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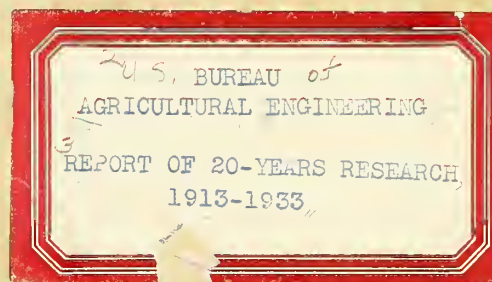
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BOOK NUMBER

873315

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BUREAU OF AGRICULTURAL ENGINEERING

Page 5:

873315

Title of project: Utilization of water in irrigation.

Sub-project no. 3: Reclamation and irrigation management of alkali lands.

This project completed 1933.

Page 6:

Title of project: Utilization of water in irrigation.

Sub-project no. 4: Drainage and irrigation management of lands overlying artesian basins.

This project discontinued 1934.

Page 11:

Title of project: Irrigation conduits and structures.

Sub-project no. 5: Canal operation, methods, and improvement.

This project discontinued 1934.

Page 15:

Title of project: Customs, regulations, and laws relating to irrigation.

Sub-project no. 3: Reorganization, financing and consolidation of irrigation enterprises.

This project discontinued 1934.

Page 20:

Title of project: Run-off and hydraulics of drainage channels.

Sub-project no. 3: Flow around channel bends and pier noses.

Title changed, 1934, to "Flow around channel bends", as work on pier noses has been completed.

Page 30:

Title of project: Drainage of farm lands.

Sub-project no. 5: Drainage index of soils.

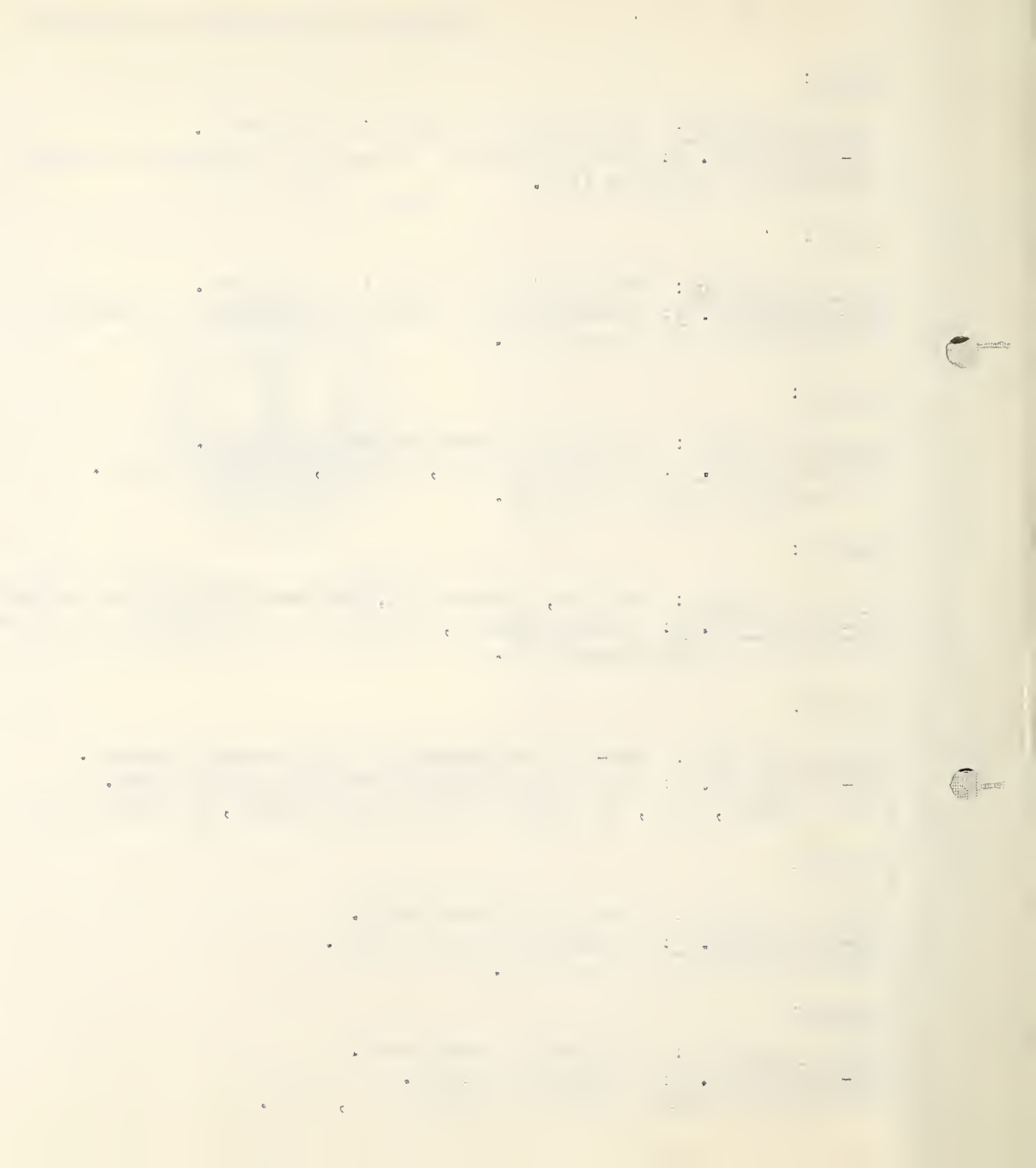
This project discontinued 1934.

Page 32:

Title of project: Drainage of farm lands.

Sub-project no. 6: Sewage irrigation.

This project to be discontinued December 1, 1933.



Between Pages 33 and 34 insert (new project):

Title of project: Drainage of farm lands (continued)

Sub-project no. 7: Irrigation in the humid section.

Date begun: July 1, 1933.

Date completed: In progress.

Authority: (Ibid).

Cost of work: Estimated for 1934, \$4,200.

Results: None.

Economic importance: There are large areas in the humid section where crop yields are frequently materially reduced by periods of drought during the growing season. In many areas, especially where high priced crops are grown, irrigation can be profitably practiced. This investigation has for its object the comparative study of modern irrigation methods and equipment and their use in areas needing additional water supply in certain seasons of the year.

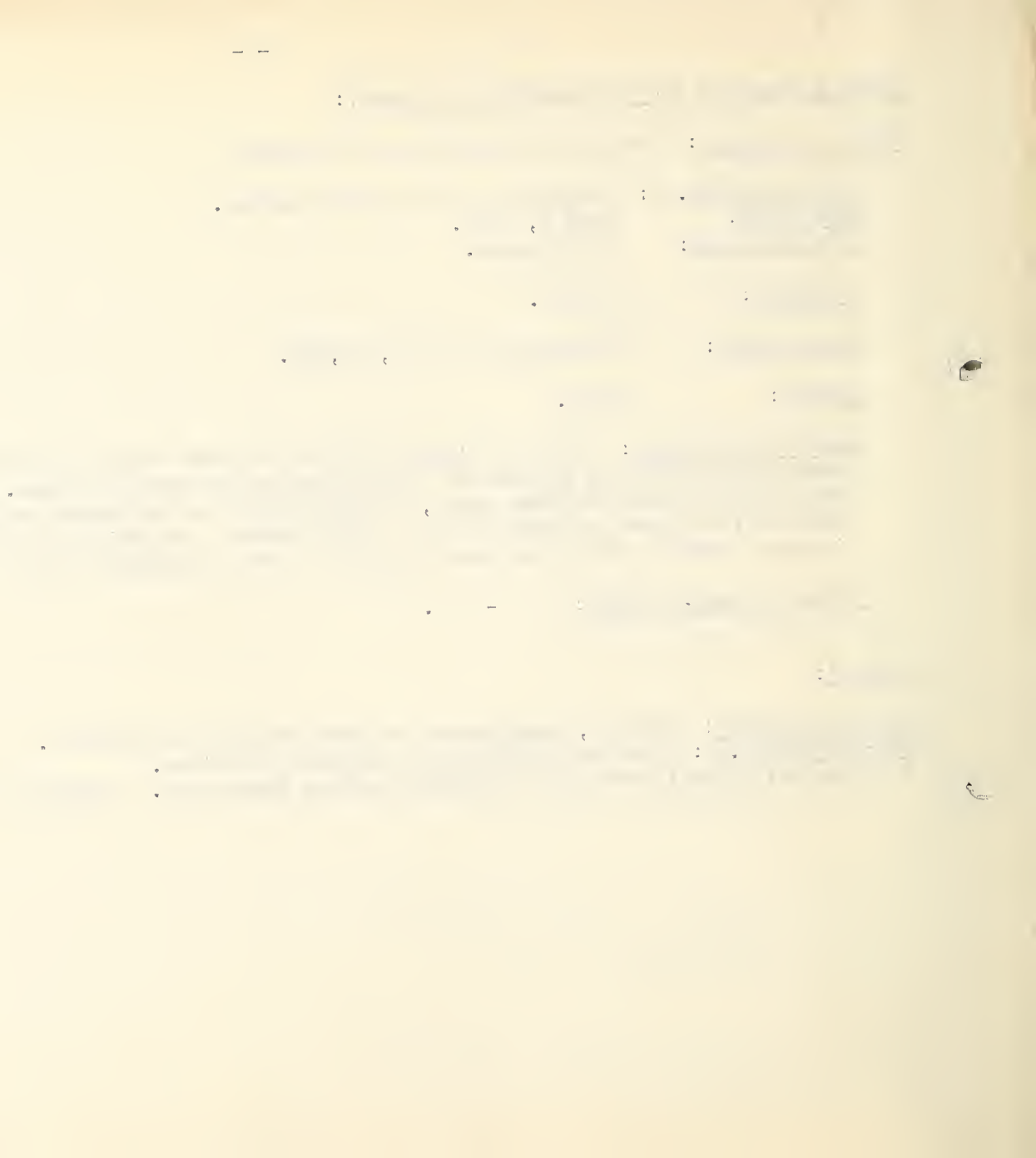
Estimated annual saving: -- .

Page 34:

Title of project: Customs, regulations and laws relating to drainage.

Sub-project no. 1: The rehabilitation of drainage districts.

This project consolidated with "Drainage district operation". (See page 36.)



BUREAU OF AGRICULTURAL ENGINEERING
SUMMARY OF RESEARCH PROJECTS
Compiled April, 1933.

Page

IRRIGATION

Utilization of water in irrigation	1
Duty of water	1
Duration1899-1933	
Annual cost.....Varied, for 1933, \$55,000.	
Estimated annual saving\$4,000,000 (citrus industry only).	
Pumping for irrigation	4
Duration1904-1933	
Annual costVaried, for 1933, \$12,500.	
Estimated annual savingEfficiency of plants have been increased.	
Reclamation and irrigation management of alkali lands	5
Duration1904-1933	
Annual costVaried, for 1933, \$3,000.	
Estimated annual savingNo basis for reliable estimate.	
Drainage and irrigation management of lands overlying artesian basins.....	6
Duration1930-1933	
Annual costVaried, for 1933, \$2,400.	
Estimated annual savingNo basis for reliable estimate.	
Irrigation conduits and structures	7
Design and invention of apparatus	7
Duration1913-1933	
Annual costVaried, for 1933, \$7,000.	
Estimated annual savingImperial Valley, California, spends as much as \$1,000,000 in removing sand from irrigation canals. Much of this could be saved by installation of sand traps.	
Silt in streams and reservoirs of Texas	8
Duration 1913-1933	
Annual cost Varied, at present approximately \$5,600.	
Estimated annual saving No basis for reliable estimate.	
Storage of water under ground	9
Duration 1933 -	
Annual cost For 1933, \$6,400.	
Estimated annual saving Flood water not stored is wasted. Underground storage where practical avoids cost of expensive structures.	

Flow of water in ditches, pipes, and other irrigation conduits.....	10
Duration.....	1916-1933
Annual cost.....	varied, at present \$5,800.
Estimated annual saving.....	no basis for reliable estimate.
Canal operation, methods, and improvement.....	11
Duration.....	1913-1933
Annual cost.....	varied, at present approximately \$1,000.
Estimated annual saving.....	no basis for reliable estimate.
Control of gravel in open channels.....	12
Duration.....	1922-1933
Annual cost.....	varied, at present approximately \$1,500.
Estimated annual saving.....	no basis for reliable estimate.
Customs, regulations, and laws relating to irrigation.....	13
Financial rehabilitation of irrigation enterprises.....	13
Duration.....	1930-1933
Annual cost.....	varied, for 1933, \$4,000.
Estimated annual saving.....	no basis for reliable estimate.
Policies governing ownership of return waters from irrigation.....	14
Duration.....	1933
Annual cost.....	for 1933, \$3,600.
Estimated annual saving.....	no basis for reliable estimate.
Reorganization, financing, and consolidation of irrigation enterprises.....	15
Duration.....	1920-1933
Annual cost.....	varied, for 1933, \$2,400.
Estimated annual saving.....	no basis for reliable estimate.

DRAINAGE AND SOIL EROSION CONTROL

Run-off and hydraulics of drainage channels.....	16
Run-off investigations.....	16
Duration.....	1913-1933
Annual cost.....	varied, for 1933, \$6,000.
Estimated annual saving.....	Savings effected in two ways and dependent upon extent of intelligent application; (1) through avoidance of use of too small sizes of drains resulting in partial or total loss of funds; (2) through avoidance of channels of too large capacity resulting in unnecessary expenditure. The difference between costs of 24-inch and 30-inch tile drains complete is about \$6,000 per mile.

Cost of pumping for drainage.....	18
Duration.....1925-1933	
Annual cost.....varied, for 1933, \$5,000.	
Estimated annual saving.....\$400,000.	
Flow around channel bends and pier noses.....	20
Duration.....1927-1933	
Annual cost.....varied, for 1933, \$13,000.	
Estimated annual saving.....no basis for reliable estimate.	
Drainage of farm lands.....	22
Maintenance of drainage channels.....	22
Duration.....1931-1933	
Annual cost.....approximately, \$3,500.	
Estimated annual saving.....no basis for reliable estimate of saving. Estimated that 75 per cent of such improvements are in need of maintenance.	
Effect of soil alkalis, soil acids, and frost on clay and concrete tile.....	24
Duration.....1921-1933	
Annual cost.....approximately \$5,000.	
Estimated annual saving.....no basis for reliable estimate.	
Drainage of sugar cane land.....	26
Duration.....1930-1933	
Annual cost.....varied, at present approximately \$6,500.	
Estimated annual saving.....Indications are that deep drainage will result in increased yield of cane from some land of at least 10 to 15 per cent.	
Ground water studies in Florida.....	28
Duration.....1932-1933	
Annual cost.....approximately, \$4,000.	
Estimated annual saving.....no basis for reliable estimate.	
Drainage index of soils.....	30
Duration.....1927-1933	
Annual cost.....approximately, \$3,000 per annum.	
Estimated annual saving.....no basis for reliable estimate.	
Sewage irrigation.....	32
Duration.....1929-1933.	
Annual cost.....approximately, \$3,400.	
Estimated annual saving.....no basis for reliable estimate. Cost of sewage disposal of one town (pop. 8,000) by irrigation, \$1,200. Cost of disposal in usual manner in other towns as follows: Pop. 4,000-\$2500; pop. 9,260 - \$7,000. Additional returns by farmers through increased crop yield and decreased fertilizer expense.	

DRAINAGE AND SOIL EROSION CONTROL (continued)

Page

Customs, regulations, and laws relating to drainage.....	34
The rehabilitation of drainage districts.....	34
Duration.....1932-1933	
Annual cost.....\$5,000.	
Estimated annual saving....no basis for reliable estimate. A satisfactory plan of rehabilitation will enable many drainage districts to avoid bankruptcy and total loss of investment of landowners.	
Drainage district operation.....	36
Duration.....1932-1933	
Annual cost.....\$5,000.	
Estimated annual saving....no basis for reliable estimate. The estimated cost of operation and maintenance of the drainage district acreage as given in the 1930 census is at least 5 per cent of the capital investment, or \$34,000,000 per annum. This work should enable drainage enterprises to materially reduce this expense. It also will serve to discourage the organization of unwise or untimely enterprises which are certain to result in losses.	
Drainage district organization, administration, and development.....	37
Duration.....1908-1923	
Annual cost.....varied from nothing to \$10,000.	
Estimated annual saving....no basis for reliable estimate.	
Control of soil erosion.....	39
Duration.....1915-1933	
Annual cost.....1915-1928, \$3,000. Present approximately \$100,000.	
Estimated annual saving....at present rate of terracing, \$1,000,000 in cost of terrace construction, \$16,000,000 in value of land protected, total \$17,000,000. Data is not available for basis of estimate of saving effected by protection of gullies by check and soil-saving dams.	
Completed projects	
Examinations and surveys.....	42
Duration.....1905-1919	
Annual cost.....averaged \$50,000.	
Estimated annual saving....millions of acres have been furnished with improved drainage and annual increase in income to landowners is undoubtedly large.	

DRAINAGE AND SOIL EROSION CONTROL (continued)

Completed projects (continued)

Flow through culverts.....	1922-1925	44
Duration.....	1922-1925	
Annual cost.....	approximately \$7,500.	
Estimated annual saving..	Large savings possible through more accurate selection of sizes of culverts, which are needed on almost every mile of road and railroad in the United States.	
Excavating machinery used in land drainage.....		45
Duration.....	1913-1917	
Annual cost.....	approximately \$3,500.	
Estimated annual saving..	Selection of right type of machine frequently results in saving of several cents per cubic yard excavated, but no basis is available for an estimate of total annual savings.	
Flow of water in drain tile.....		46
Duration.....	1915-1919	
Annual cost.....	approximately \$8,000.	
Estimated annual saving..	The new formula developed for computing the flow of water in large tile enables the saving of \$500 to \$1500 per mile of installation of such structures but no data are available on which to base a reliable estimate of total savings.	
Reclamation of tidal marshes.....		47
Duration.....	1906, 1910, and 1911.	
Annual cost.....	approximately \$800.	
Estimated annual saving..	no basis for a reliable estimate.	
Design of drainage structures.....		48
Duration.....	1922-1925	
Annual cost.....	approximately \$3,000.	
Estimated annual saving..	Effective and economical designs for building new structures and replacing old ones will materially reduce the cost to the owner, but no estimate can be made of the annual savings resulting from this work.	

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Completed projects (continued)

| | |
|---|----|
| Depth and spacing of tile drains..... | 49 |
| Duration.....1911-1917 | |
| Annual cost.....approximately \$4,000. | |
| Estimated annual saving...The results of this work permit a saving of \$15 to \$20 or more per acre in installing tile drainage systems in certain regions, but there are no data available on which to base a reliable estimate of annual savings. | |
| Irrigation in the humid region..... | 50 |
| Operation and design of pumping plants for rice irrigation..... | 50 |
| Duration.....1928-1930. | |
| Annual cost.....approximately \$2,500. | |
| Estimated annual saving...Application of results of this investigation should result in savings of \$300,000 per year in cost of pumping, and also result in increased crops. | |
| Irrigation in Florida..... | 52 |
| Duration.....1909-1916 | |
| Annual cost.....approximately \$2,000. | |
| Estimated annual saving...In dry years returns from irrigated land are frequently double those on unirrigated land, and in periods of extreme drought irrigation may mean the difference between a good crop and a complete failure. | |
| Surface irrigation in the eastern states..... | 53 |
| Duration.....1909-1923 | |
| Annual cost.....Has varied widely. Approximately \$300 per annum during last 10 years. | |
| Estimated annual saving...In many areas, especially where high-priced crops are grown, irrigation can be practiced at savings of \$50 to \$100 per acre as compared with other methods generally used. | |
| Tests of spray irrigation equipment..... | 54 |
| Duration.....1928-1929 | |
| Annual cost.....approximately \$750. | |
| Estimated annual saving...This project will enable landowners to avoid purchase of inefficient and unsuitable equipment. | |
| Utilization of land in drainage enterprises..... | 55 |
| Duration.....1926-1928 | |
| Annual cost.....approximately \$2800. | |
| Estimated annual saving...The facts developed in this study should be valuable in preventing inauguration of unwise drainage undertakings. | |

DRAINAGE AND SOIL EROSION CONTROL

Completed projects (continued)

| | |
|---|---|
| Pumping plants for Gulf Coast marsh lands..... | 57 |
| Duration..... | 1906-1922. Work intermittent. |
| Annual cost..... | approximately \$3,500 per year when active. |
| Estimated annual saving..... | No data are available for reliable estimate of annual saving. |
| Factors influencing the design, construction, and maintenance of large tile drains. Economical use of large tile for land drainage..... | 58 |
| Duration..... | 1925-1926 |
| Annual cost..... | approximately \$2,500. |
| Estimated annual saving..... | No data are available for a reliable estimate of annual saving. |

DEVELOPMENT OF FARM LANDS

| | |
|--|---------------------------------|
| Investigations of farm land development..... | 60 |
| Duration..... | 1927-1933 |
| Annual cost..... | varied; for 1933, \$14,650. |
| Estimated annual saving..... | No basis for reliable estimate. |

STRUCTURES

| | |
|---|--|
| Livestock shelters and appurtenances..... | 61 |
| Relation of stable air conditions to milk production..... | 61 |
| Duration..... | 1930-1933 |
| Annual cost..... | varied; \$8,400 in 1933. |
| Estimated annual saving..... | Difficult to estimate. If the recommended practices affect only 5 per cent of the 24 million cows in the United States saving should amount to more than a million dollars per year. |
| Dairy barn ventilation..... | 62 |
| Duration..... | 1921-1930 |
| Annual cost..... | approximately \$2,000. |
| Estimated annual saving..... | Savings lie in improved health of cows, more and better milk produced and increased life of barns. Monetary saving is large but difficult to estimate. |
| Livestock buildings and equipment..... | 64 |
| Duration..... | 1922-1929 |
| Annual cost..... | approximately \$1,000 per year. |
| Estimated annual saving..... | No basis for reliable estimate. |

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|---|--|
| Improvement of farm buildings..... | 65 |
| Improvement of farm houses..... | 65 |
| Duration..... | 1932-1933 |
| Annual cost..... | \$4,200 in 1932, \$2,850 in 1933. |
| Estimated annual saving..... | Greatest saving is in the increased satisfaction and improved living conditions resulting from the greater convenience, comfort, and good appearance of a well planned house, either new or remodeled. |
| Use of steam for soil sterilization..... | 67 |
| Duration..... | 1932-1933 |
| Annual cost..... | \$1,800 for 1932; \$3,800 for 1933. |
| Estimated annual saving..... | Anticipated substantial savings to greenhouse owners and tobacco growers. |
| Study of modern vaporizing oil burners..... | 68 |
| Duration..... | 1933 |
| Annual cost..... | approximately \$2,000. |
| Estimated annual saving..... | Increased convenience and comfort to purchasers of more efficient equipment, and avoidance of loss through purchase of inferior burners. |
| Application of unit heaters to greenhouses..... | 69 |
| Duration..... | 1933 |
| Annual cost..... | \$1,350 |
| Estimated annual saving..... | Since this is a pioneer work, no data on which to base a reliable estimate of cost is available. |
| Research in farm structures (a field survey of research by State experiment stations and private concerns)..... | 70 |
| Duration..... | 1929-1930 |
| Annual cost..... | Total cost \$8,000. |
| Estimated annual saving..... | Considerable savings to State experiment stations through avoidance of duplication of work, and clearer cooperation between the various agencies, resulting in better service to farmers. |
| Farm building construction details..... | 72 |
| Duration..... | 1930-1932 |
| Annual cost..... | approximately \$3,000. |
| Estimated annual saving..... | No basis for reliable monetary estimate but adoption of improved and new methods results in continuous savings. |

STRUCTURES (continued)

Page

Improvement of farm buildings (continued)

| | |
|---|--|
| Improvement of dairy barn design for southeast Pennsylvania..... | 74 |
| Duration..... | 1929-1931 |
| Annual cost..... | Total cost approximately \$3,000. |
| Estimated annual saving..... | Savings result from prolonged life of structures, reduced labor in caring for cows, improved health and productivity of cows, and a widened market for milk. |
| Domestic oil burners..... | 75 |
| Duration..... | 1924-1927 |
| Annual cost..... | approximately \$5,500 per year. |
| Estimated annual saving..... | Large savings have resulted from aid to home-owners in selection of suitable equipment and in discontinuance of some oil burners and improvement of others by manufacturers. |
| Greenhouse heating..... | 77 |
| Duration..... | 1929-1932 |
| Annual cost..... | approximately \$1,500 per year. |
| Estimated annual saving..... | Considerable savings should result, but no basis for reliable estimate is available. |
| Cheese factories and creameries..... | 78 |
| Duration..... | 1928-1929 |
| Annual cost..... | approximately \$1,250. |
| Estimated annual saving..... | no basis for reliable estimate. |
| Storage and transportation of farm products..... | 79 |
| Transportation and storage of fruits and vegetables..... | 79 |
| Duration..... | 1922-1933 |
| Annual cost..... | has varied, \$7,000 for 1933. |
| Estimated annual saving..... | Savings are in nature of improved supply of fresh fruits and green vegetables in all markets throughout the year. |
| Relation of storage house construction and management to storage losses of white potatoes.. | 81 |
| Duration..... | 1926-1928; 1932-1933. |
| Annual cost..... | varied, \$6,500 in 1933. |
| Estimated annual saving..... | Application of findings should reduce present rate of storage loss by half, increase useful life of storage buildings, and improve quality of potatoes reaching consumer. |
| Grain storage..... | 82 |
| Duration of work..... | 1928-1933 |
| Annual cost..... | varied; \$3,000 in 1933. |
| Estimated annual saving..... | Savings will result from reduced losses of stored grain and increased life of storage structures. |

Storage and transportation of farm products (continued)

| | |
|---|--|
| Sweet potato storage..... | 84 |
| Duration..... | 1917-1929 |
| Annual cost..... | approximately \$800. |
| Estimated annual saving..... | Recommended practices have been widely adopted and have resulted in increased marketing as well as reduced storage losses of sweet potatoes. |
| Mechanical refrigeration on dairy farms..... | 85 |
| Duration..... | 1930-1933 |
| Annual cost..... | varied; \$1,090 in 1933. |
| Estimated annual saving..... | Savings will result from aid in selecting proper type of cooling equipment and avoidance of losses of milk from improper cooling. |
| Effect of cooling pipe location, cooling surface area, and refrigerant temperature on temperature distribution and relative humidity of cold storage rooms..... | 86 |
| Duration..... | 1928-1932 |
| Annual cost..... | approximately \$2,500. |
| Estimated annual saving..... | No basis for a reliable estimate, but application of findings should result in a lower cost of refrigeration for farm products, and reduction of losses due to uneven temperature distribution in cold storage rooms used for farm products. |

MECHANICAL EQUIPMENT

| | |
|--|---|
| Mechanical control of European corn borer..... | 87 |
| Duration..... | 1927-1933 |
| Annual cost..... | varied; \$63,200 for 1933. |
| Estimated annual saving..... | If plowing as recommended for corn borer control were generally practiced a large saving would ensue from the reduction in power requirements and cost. An increase of 16 per cent in tonnage of ensilage per acre may be obtained by using low cutting attachments developed by the Bureau for standard corn binders. |
| Fertilizer distributing machinery..... | 90 |
| Duration..... | 1924-1933 |
| Annual cost..... | varied; \$19,600 for 1933. |
| Estimated annual saving..... | The indications are that the efficiency of fertilizers (ratio of fertilizer applied to fertilizer utilized by plants) might be increased 10 per cent by accurate and proper machine application. Such an increase in the efficiency of fertilizer would result in an increase of approximately \$150,000,000 in the value of crops produced annually. |

MECHANICAL EQUIPMENT (continued)

| | Page |
|---|------|
| Sugar beet production machinery..... | 92 |
| Duration.....1928-1933 | |
| Annual cost.....varied; \$14,200 for 1933. | |
| Estimated annual saving.....The cross blocker, where used, reduces the hand labor of that operation by approximately 30 per cent. An improved harvester as well as a seeder will effect a total reduction of 50 per cent in the cost of producing, harvesting and loading the crop. | |
| Cotton production machinery..... | 93 |
| Duration.....1931-1933 | |
| Annual cost.....varied; \$16,300 for 1933. | |
| Estimated annual saving.....No basis for reliable estimate. | |
| Sugar cane harvesting machinery..... | 95 |
| Duration.....1931. Project was begun in April, 1931, and stopped in July of the same year on account of death of engineer in charge and inability to replace him. | |
| Annual cost.....\$2,000 (total). | |
| Corn production machinery..... | 96 |
| Duration.....1931-1933 | |
| Annual cost.....varied; for 1933, \$14,700. | |
| Estimated annual saving.....No basis for reliable estimate. | |
| Utilization and cost of farm power and machinery..... | 98 |
| Use of power and machinery in Pennsylvania..... | 98 |
| Duration.....1927 | |
| Annual cost.....\$1,000. | |
| Estimated annual saving.....No basis for reliable estimate. | |
| Utilization and cost of farm power..... | 100 |
| Duration.....1929-1933 | |
| Annual cost.....varied; \$3,100 for 1933. | |
| Estimated annual saving.....No basis for reliable estimate. | |
| Power and machinery in agriculture..... | 101 |
| Duration.....1929-1933 | |
| Annual cost.....varied; \$3,000 for 1933. | |
| Estimated annual saving.....No basis for reliable estimate. | |

MECHANICAL EQUIPMENT (continued)

| | Page |
|--|---|
| Machinery for controlling insect pests..... | 102 |
| Development of cotton dusting machinery..... | 102 |
| Duration..... | 1917-Sept. 1931. |
| Annual cost..... | \$7,500 (total cost). |
| Estimated annual saving..... | The annual savings in normal times approximate 25 per cent of the then value of cotton grown in areas where dusting is practiced. |
| Southern field crop spraying and dusting investigations..... | 103 |
| Duration..... | 1931-1933. |
| Annual cost..... | varied; \$6,000 for 1933. |
| Estimated annual saving..... | The work has not progressed far enough to justify an estimate of probable savings. |
| Mechanical control of the pink bollworm of cotton..... | 104 |
| Duration..... | 1929-1933 |
| Annual cost..... | varied, \$5,000 for 1933. |
| Estimated annual saving..... | If repressive measures are generally applied, probably 25 to 50 per cent of the cotton crop in the present bollworm area will be saved. |
| Artificial drying of crops..... | 105 |
| Harvesting and artificial drying of rice..... | 105 |
| Duration..... | 1930-1932 |
| Annual cost..... | \$7,500 (total cost). |
| Estimated annual saving..... | There is no basis for reliable estimate of the total savings resulting from the project but at one drier where observations were made the operator was able to double the capacity of his drier and reduce the operating cost per bushel of rice dried by 50 per cent with no reduction in the milling quality of the rice by making use of the facts developed by the project. |
| Forage crop drying..... | 107 |
| Duration..... | 1926-1933 |
| Annual cost..... | varied; \$4,100 for 1933. |
| Estimated annual saving..... | No basis for reliable estimate. |

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COTTON GINNING

Cotton ginning investigations..... 109

Duration.....1926-1933

Annual cost.....varied; \$48,630 for 1933.

Estimated annual saving.....No estimate can be made of the annual savings which have resulted from the improvements already developed in the methods of ginning cotton. As an example of what may be expected when these processes come into general practice, it may be said that it has been found that the artificial drying of seed cotton has saved from 60¢ to as much as \$5.00 or more per bale. This process has also been very effective in reducing the cost of ginning, since thoroughly dried cotton gins with less power and less interruption from stoppages, and ginning can be carried on continuously without reference to weather conditions.

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BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF IRRIGATION

1

Title of project: Utilization of water in irrigation.
Date begun: 1899.
Date completed: In progress.

Authority: Agricultural Appropriation Act under item for Bureau of Agricultural Engineering "for investigating and reporting upon the utilization of water in farm irrigation and the best methods to apply in practice".

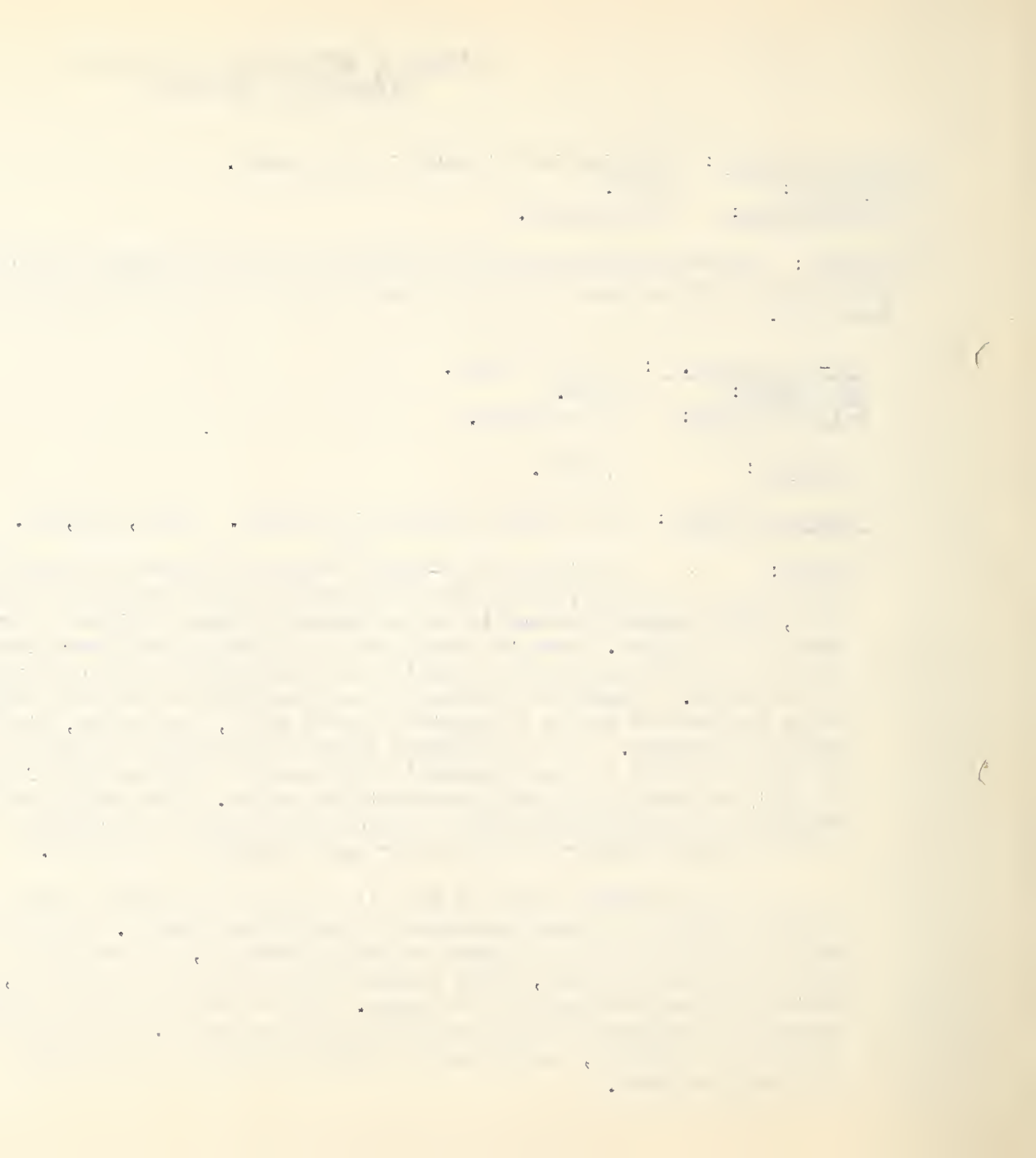
Sub-project no. 1: Duty of water.
Date begun: 1899.
Date completed: In progress.

Authority: (Ibid).

Cost of the work: Has varied between wide limits. 1933, \$55,000.

Results: In 1898 the so-called "duty of water" was determined by measuring the amount of water used on the different crops by various farmers throughout the irrigated region. It was, in fact, quite commonly deemed to be the amount of water applied in practice irrespective of requirements of the plant. Some 20 years ago our investigational work took practical cognizance of the fact that the amount of water applied in practice was not necessarily the amount of water required by the crops. A complete realization had developed of the fact that methods used in applying the water in practice should be adapted to soil types, topography, kind of crop, scarcity of water, and other factors. As a consequence there was launched a program of a study of water requirements of plants both as to total seasonal requirement and the number of irrigations and amount of water to apply at each irrigation throughout the season. Thus during this period accurate scientific determinations have been made of the economic amount of irrigation water necessary for the production of a large number of crops under many different conditions.

In connection with this work it has been found that waste and loss of water in canals and ditches greatly increased the costs of irrigation farming. Chief amongst the methods of saving water are the lining of channels to prevent seepage, the reduction of non-economic growths such as weeds and aquatic plants, which consume water to no useful purpose, and improved methods of preparing the land and applying the water. All of these have been studied and experimented upon and substantial progress has been made in their evaluation. The knowledge gained has been applied in practical irrigation, and in many instances as much as 50 per cent of the waste of earlier periods has been retrieved.



Title of project: Utilization of water in irrigation (continued).

Sub-project no. 1: Duty of water (continued).

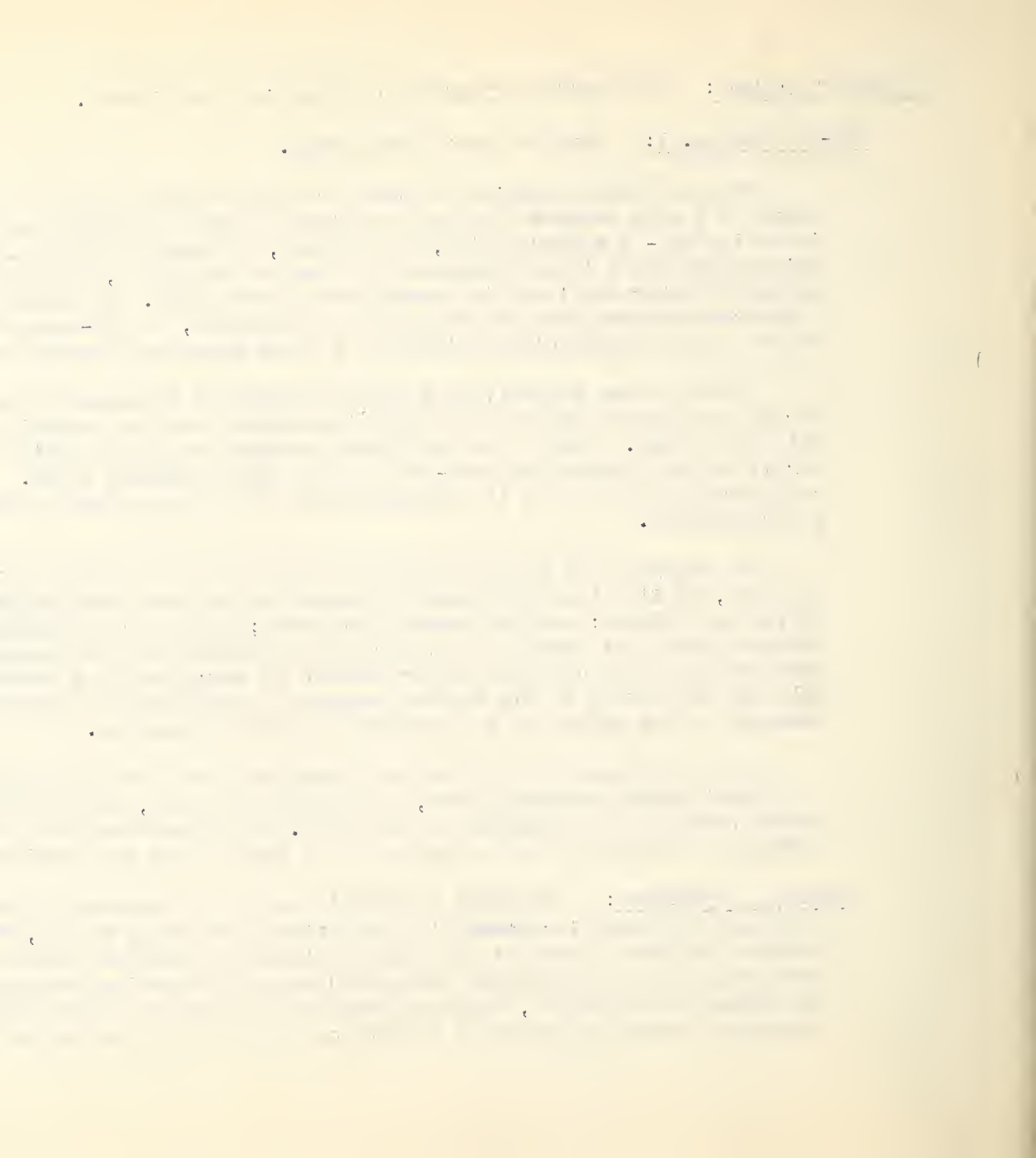
Another feature looking to economical use of water that has developed during the past 20 years is a crop program that will utilize the water as nearly as can be at the time when it is available - a synchronizing, so to speak, of demand with supply. In the streams of the arid region there is an abundance of water in the spring, but as the season progresses the amount of water available in these streams grows less. By planning and putting into effect a program of crops that mature early in the season, at mid-season, and late in the season, the water is more completely utilized and a large measure of danger of loss of crops eliminated.

In this same connection we have made studies to determine the value of supplementary water during the latter part of the irrigation season when the natural flow of the streams is considerably diminished. One or two additional irrigations in the latter part of the growing season will permit the cultivation of late-maturing and more valuable crops. We have determined that a considerably higher cost is permissible for this supplemental water than would be possible for a stream right.

In studying the losses of water that occur in practical irrigation and especially upon the farm, we find that the three different sources are percolation of water below the root zone of the crop plants; surface run-off and waste; and direct evaporation from the soil surface. In studying this last feature of evaporation in connection with orchards, it has been proven by us that the amount of cultivation recommended 20 years ago to conserve soil moisture is not justifiable and the saving to the farmers engaged in the growing of rowed crops or orchards through the decrease in the number of cultivations has been tremendous.

The development within the past three or four years has been to indicate that it is possible to control within certain limits, in commercial groves, the time of blooming of certain of the citrus trees and the ripening of the fruit. This promises to change completely some of the prevalent practices in the culture of this crop in the arid region.

Economic Importance: The total irrigated area of the western United States in 1930 was 19,547,544 acres and the total investment in irrigation enterprises was \$1,032,755,790. Since the social and economic welfare of many of the western States is dependent upon the success of irrigation, and because the amount of available irrigation water is becoming inadequate in many localities to meet the demands made upon it, anything which can be done to insure the economical use of water is of tremendous social and economic importance to the 19 States having large irrigation interests.

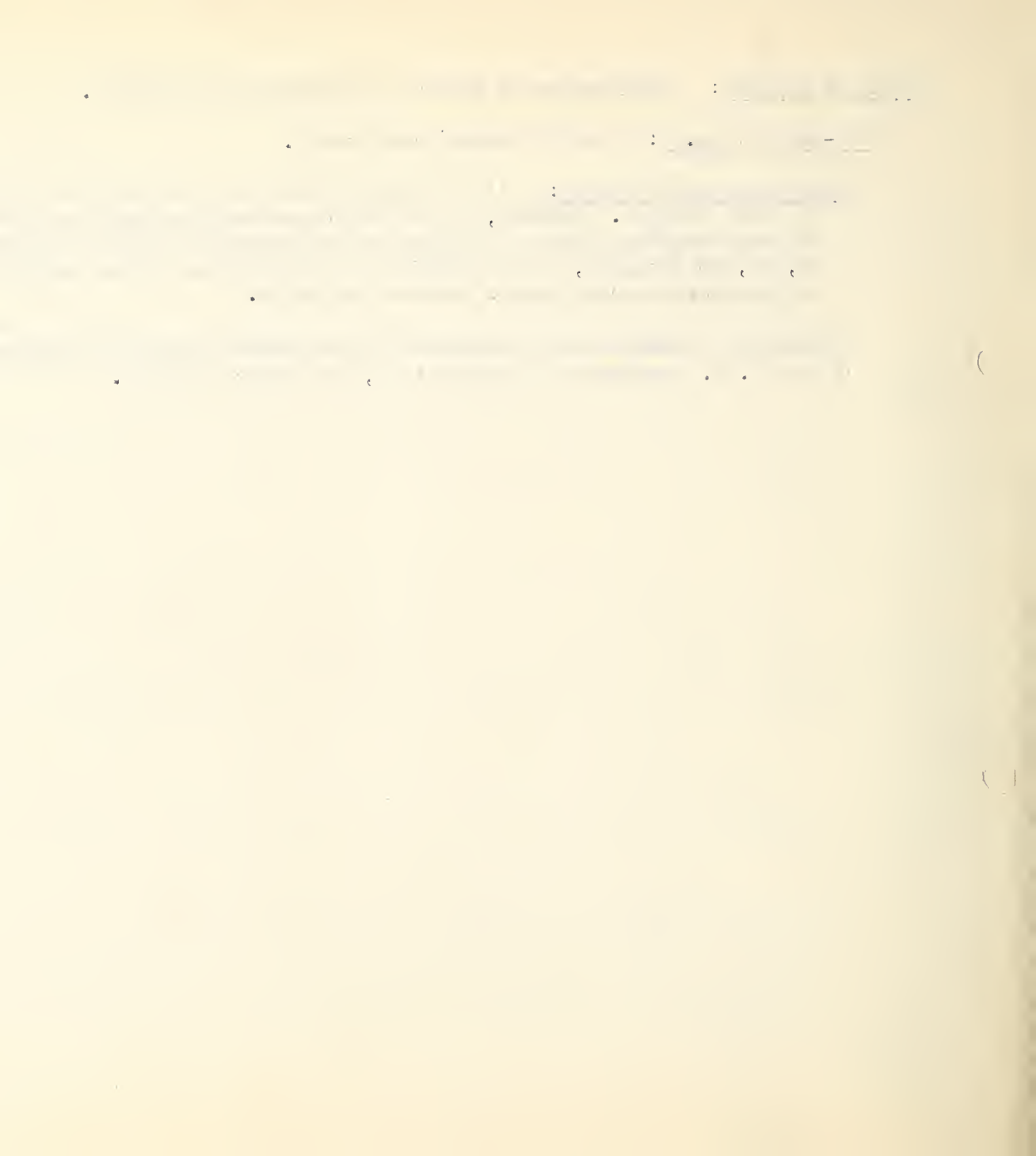


Title of project: Utilization of water in irrigation (continued).

Sub-project no. 1: Duty of water (continued).

Estimated annual saving: It is very difficult to even estimate the annual saving to those benefited by these studies. However, it is stated upon unimpeachable authority that the results of the duty of water studies alone in California have saved the single industry of citrus fruit production \$4,000,000 annually, not to mention the added value of the product. Comparable estimates on the savings made on other crops are not available.

This work is carried on in cooperation with State Agricultural Experiment Stations, various Bureaus of the U. S. Department of Agriculture, and other agencies.



Title of project: Utilization of water in irrigation (continued).

Sub-project no. 2: Pumping for irrigation.

Date begun: 1904.

Date completed: In progress.

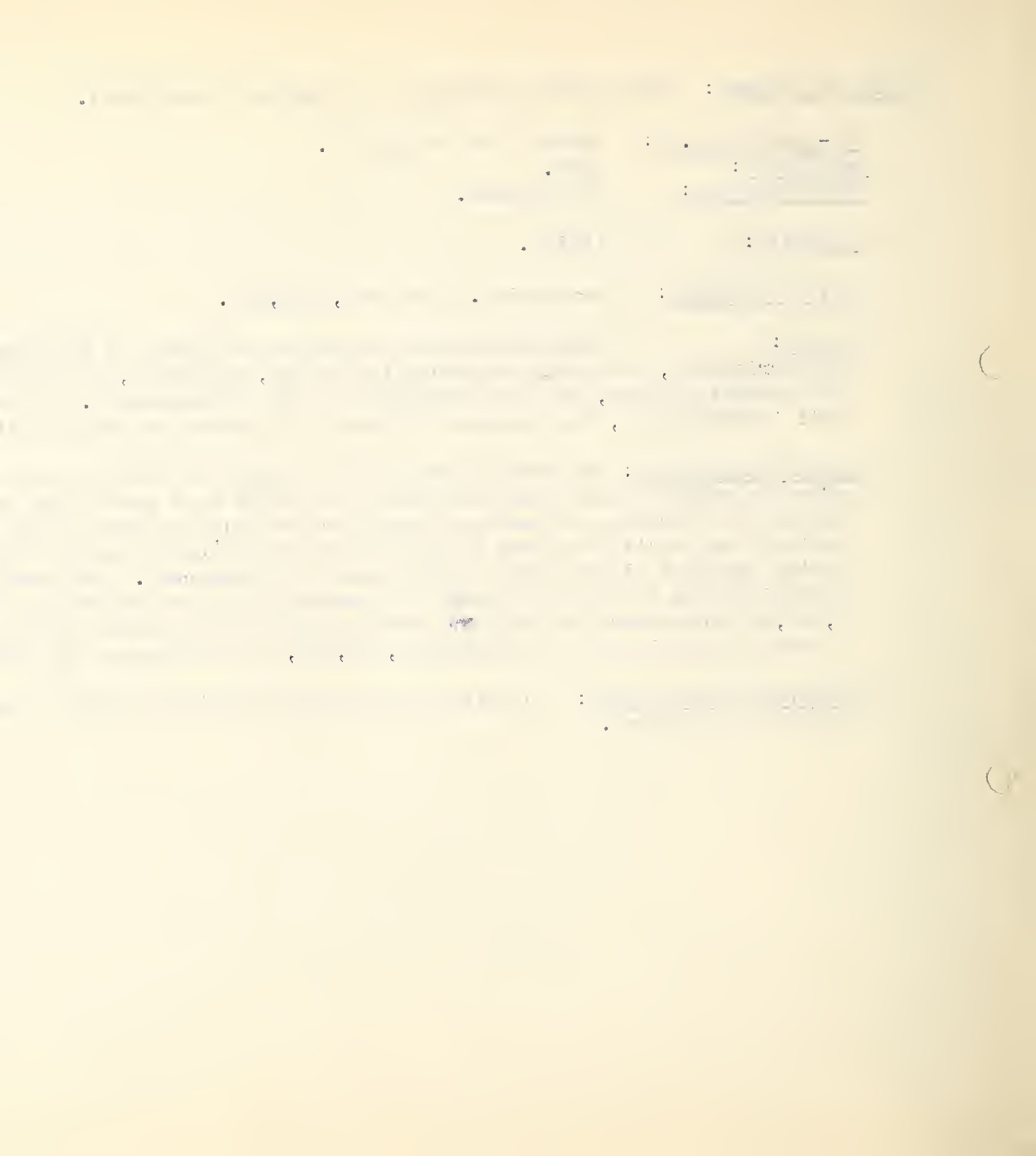
Authority: (Ibid).

Cost of the work: Has varied. For 1933, \$12,600.

Results: This project covers studies and tests of developments or improvements in pumping for irrigation, including the mechanical units, the wells, the equipment, the method of installation, the assembled plant, and the efficiency of the various units. By reason of the facts developed in this investigation, the average efficiency of irrigation pumping plants has been greatly increased.

Economic importance: The growing demand for irrigation water has resulted in increased pumping, and often in pumping water from depths which formerly were considered prohibitive. Thus, the economical design and operation of pumping plants becomes more and more necessary. In the course of this investigation plants have been found with an overall efficiency of less than 40 per cent, while the better designed plants have an efficiency of 70 per cent. The great value of a project which results in an increase in the efficiency of a pumping plant can be realized when it is considered that 6,085,501 acres were entirely or partly supplied with pumped water in 1929, and that the investment in such enterprises in 1930 was \$553,456,976, an increase of 210 per cent over the figures for 1920.

Estimated annual saving: No data are available on which to base an estimate of the annual saving due to this project.



Title of Project: Utilization of Water in Irrigation.(Continued)

Sub-project No. 3: Reclamation and irrigation management of alkali lands.

Date begun: 1904.

Date completed: In progress. To be completed during fiscal year 1933.

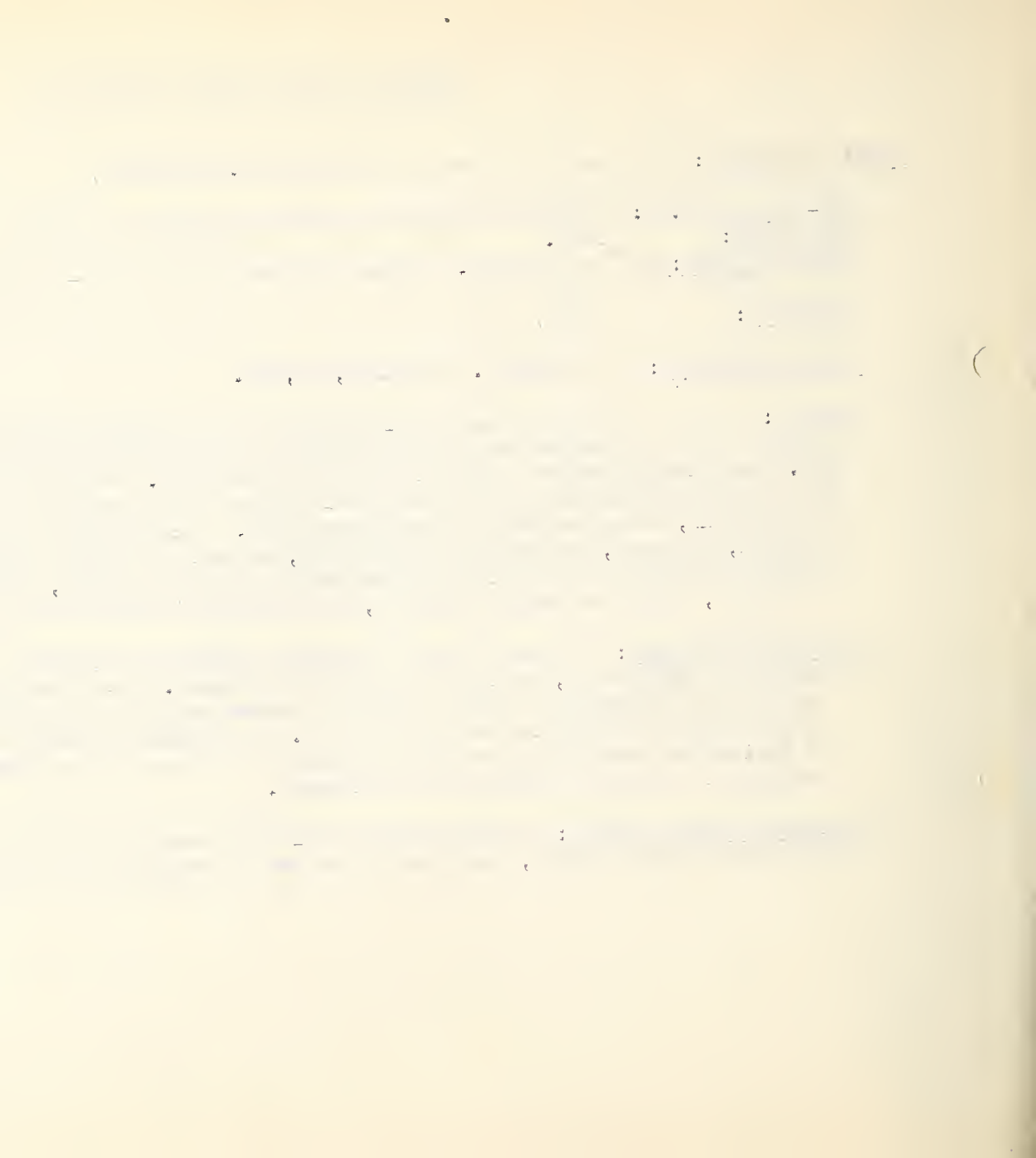
Authority: (Ibid)

Cost of the work: Has varied. For 1933, \$3,000.

Results: The purpose of this project is to determine some method or treatment which could be used to restore the productivity of irrigated land which had become too alkalied for use. The alkali problem divides itself into two parts. For the white alkali the methods of drainage introduced many years ago by this Bureau have proven entirely effective. For the black alkali, other methods are found necessary. A long series of experiments utilizing cultural, drainage, and chemical treatments, as well as combinations of these, have resulted in findings that heavy irrigation together with adequate drainage, gives best results. Chemical treatments, while partially effective, are too high in cost to be practical.

Economic importance: In many areas of the West continued irrigation brings the alkali salts to the surface of the ground, making it infertile or barren. That good drainage will largely prevent such action has become so well known that common practice for some areas is to install drains at the time the irrigation works are built. The Census for 1930 reports that 10,611,415 acres in irrigation enterprises are either drained or in need of drainage, but an unknown part of this drainage is for lands which are not alkaline.

Estimated annual savings: Large areas of irrigated lands have been reclaimed by the methods developed by this Bureau, but there is no way of computing the annual savings.



Title of project: Utilization of water in irrigation (continued).

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Sub-project no. 4: Drainage and irrigation management of lands overlying artesian basins.

Date begun: 1930.

Date completed: In progress. To be completed during fiscal year 1934.

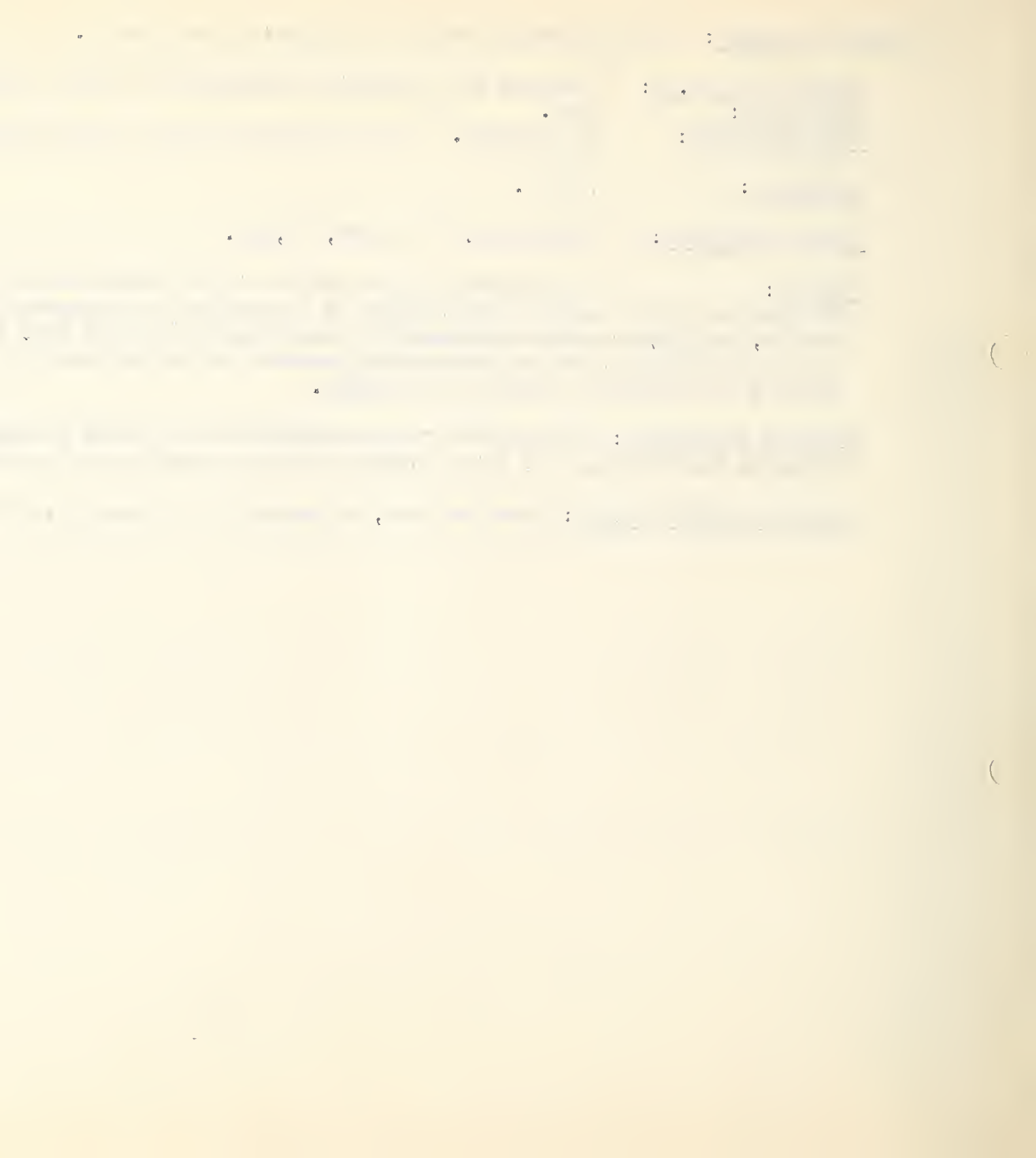
Authority: (Ibid).

Cost of the work: Has varied. For 1933, \$2,400.

Results: The purpose of this project is to determine the best and most economical method of draining lands that are waterlogged as a result of the upward movement of water from artesian basins, and the irrigation management of such lands needed to make them productive. Results so far obtained indicate that the hydrostatic pressure may be relieved by the installation of wells from which the underground water may be pumped.

Economic importance: The results of this work will be of value in reclaiming lands overlying the artesian basins which are quite numerous in some sections of the country.

Estimated annual saving: None to date, as method of treatment is not yet fully determined.



Title of Project: Irrigation Conduits and Structures.
Date Begun: 1913
Date Completed: In progress.

Authority: Agricultural Appropriation Act under item for appropriation to the Bureau of Agricultural Engineering "for investigations, experiments, demonstrations involving the application of engineering principles to agriculture **** the flow of water in ditches, pipes, and other conduits, the duty, apportionment, and measurement of irrigation water".

Sub-project No. 1: Design and Invention of Apparatus.
Date Begun: 1913.
Date Completed: In progress.

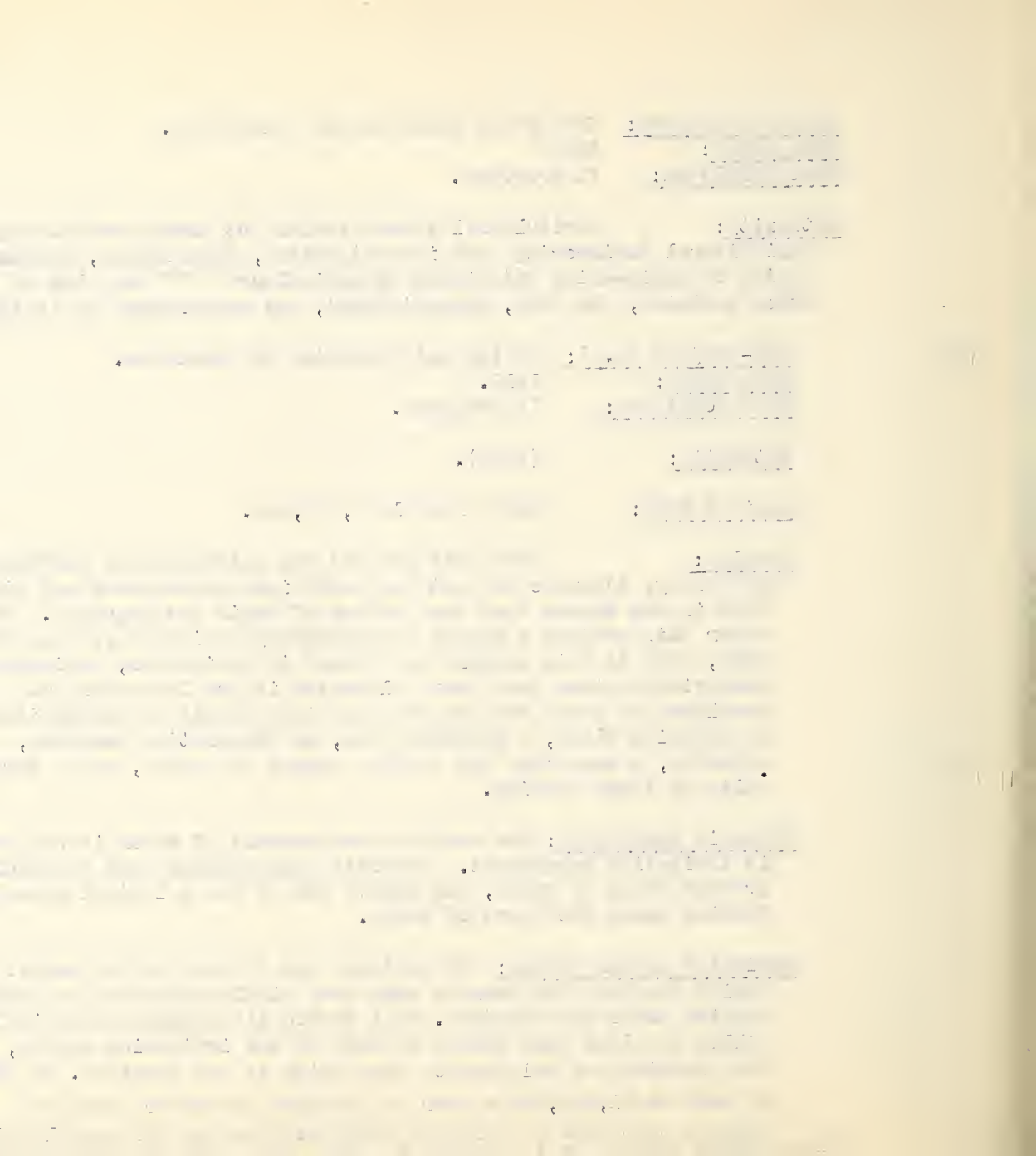
Authority: (Ibid).

Cost of Work: Has varied 1933, \$7,000.

Results: When this project was initiated the instruments used for measuring water were not always adequate to meet the conditions encountered and did not always yield quantitative data in the degree that the purpose of their use required. Through the studies carried on under this project a number of noteworthy devices have been developed which are universally used, both in this country and abroad in irrigation, drainage, and allied work. Many commercial measuring devices have been calibrated in our laboratory and tables, curves, and nomographs developed to adapt the use of these instruments to irrigation conditions as found in the West. A measuring flume, a measuring box, an integrating recorder, a double head water stage recorder, a sand trap for ridding canals of debris, and a current meter were the direct results of these studies.

Economic Importance: The accurate measurement of water is one of the most important details in irrigation management. Accurate measurements tend to secure the economical use of water, prevent waste of water, and remove one of the principal causes of complaints and dissatisfaction among the users of water.

Estimated Annual Saving: No estimate can be made of the annual saving resulting from this work. During the past two years a sand trap riffle deflector has been invented in the course of the studies under this project. This device discharges automatically the sand and gravel or so-called bed load that occurs in many of our irrigation canals, thus obviating a great deal of the cleaning and maintenance work which is now required. In the Imperial Valley of California as much as \$1,000,000 a year is expended to remove sand from the irrigation canals and it appears that much of this sum could be saved by the installation of sand traps. This work is carried on in cooperation with the Colorado Agricultural Experiment Station.



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Title of Project: Irrigation Conduits and Structures.

Sub-project No. 2: Silt in Streams and Reservoirs of Texas.

Date Begun: 1913.

Date Completed: In progress. To be completed during fiscal year 1934.

Authority: (Ibid)

Cost of Work: Varied. At present approximately \$5,600 per annum.

Results: In designing reservoirs for the storage of water for irrigation or power, it is necessary to know the amount of silt which may be brought into the reservoir since the useful life of a reservoir is sometimes determined by the length of time which will elapse before it becomes filled with sediment. The purpose of this investigation is to determine the percentage of silt in various Texas streams by weight and volume. The distribution of silt in the cross section of streams, the amount of sand and silt rolling along the bottom of the stream, and the amount of silt actually deposited in reservoirs. A great many samples of river water have been obtained from a number of Texas streams under varying conditions of flow and all the larger reservoirs of the State have been investigated and the actual silt deposits have been measured. Sufficient data has already been obtained to express the amount of silt carried by typical Texas streams in terms of acre-feet of runoff per square mile of drainage area per year and also as a per cent by weight of the total inflow of water. The determination of the rates of filling up of typical reservoirs has not yet been completed.

Economic Importance: While the work on this project has been limited to the streams of Texas, the results will be applicable wherever similar conditions prevail. These results should be of great importance in designing storage reservoirs in the southwestern part of the United States.

Estimated Annual Savings: There is no information available on which to base an estimate of the amount of annual savings which will result from this project.

This work is carried on in cooperation with the Texas Board of Water Engineers.

Title of Project: Irrigation Conduits and Structures.

Sub-project No. 3: Storage of Water Under Ground.

Date Begun: 1933.

Date Completed: In progress.

Authority: (Ibid).

Cost of Work: ~~Has varied.~~ For 1933 \$6,400.

Results: The purpose of this investigation is to develop means and methods whereby the flood flows of streams can be retarded and diverted from their natural course to lands selected and prepared for storing these waters under ground for later use in irrigation by means of pumping. Investigations were started this year on a 200 acre tract in southern California. Data are being secured as to the practicability of underground storage.

Economic Importance: The underground water supply from which water is pumped for irrigation in many sections of the West is becoming more and more depleted as the areas cultivated are increased and as the seasons of scant rainfall have occurred at closer intervals. Consequently the pumping and cost per acre-foot of water have increased to such a point as to require remedial action. Methods of replenishing the underground water supply are of immediate importance in many sections of southern California and in certain areas in Utah, Oregon, Arizona, and Texas.

Estimated Annual Savings: None.

No work is being done on this project by State experiment stations.

Title of Project: Irrigation Conduits and Structures.

Sub-project No. 4: Flow of Water in Ditches, Pipes, and Other Irrigation Conduits.

Date Begun: 1916.

Date Completed: In progress.

Authority: (Ibid)

Cost of Work: Varied. At present \$5,800 per annum.

Results: This project covers studies of the hydraulic factors which may properly be used in computing the flow of water in ditches and conduits. Formulas for computing the flow of water in wooden pipe, irrigation channels, wood stave pipes, concrete pipes, and riveted steel pipes have been developed which are in constant use by irrigation engineers in this country and abroad. The work in hand at present is the development of a similar formula for the flow of water in flumes and in tunnels.

Economic Importance: At the present time there is invested in irrigation works a little over one billion dollars and a large part of this investment is represented by conveying channels. The development of correct hydraulic formulas for computing the flow of water in conduits of various kinds will result in a more economical design of such channels which in turn will give better efficiency and less cost. The proper hydraulic design of conduits, laterals, and farm ditches may result in materially reducing the cost of construction.

Estimated Annual Savings: No estimate can be made of annual savings due to this work.

No similar investigations are being conducted by State experiment stations.

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Title of Project: Irrigation Conduits and Structures.

Sub-project No. 5: Canal Operation, Methods, and Improvement.

Date Begun: 1913.

Date Completed: In progress.

Authority: (Ibid)

Cost of Work: Varied. At present approximately \$1,000, per year.

Results: As a result of this investigation there have been developed from time to time methods of cleaning canals of debris, weed growth, and silt deposits which are much more efficient than methods formerly used. A great deal of work has been done in the development of concrete and other forms of lining for the purpose of preventing loss of irrigation water by seepage and the prevention of plant growth in the canals.

Economic Importance: Under this study falls the many factors to be considered in the operation of irrigation canal systems. By no means is all the water turned into a canal put to beneficial use. Conveyance losses range from a negligible amount to as high as 25 to 30 per cent of the diverted supply. Losses in the canals, laterals, and farm ditches all contribute to a total which might mean the difference between the economic success or failure of an enterprise. The growth of alga, weeds, chemical and silt deposits in canals contribute to the frictional resistance to the flow of water and reduce the velocity and the availability of the supply. These problems are found wherever irrigation water is used.

Estimated Annual Savings: No information is available as to the amount of annual savings.

No similar work is being conducted by State agricultural experiment stations.

Title of project: Irrigation Conduits and Structures.

Sub-project no. 6: Control of Gravel in Open Channels

Date begun: 1922.

Date completed: In progress.

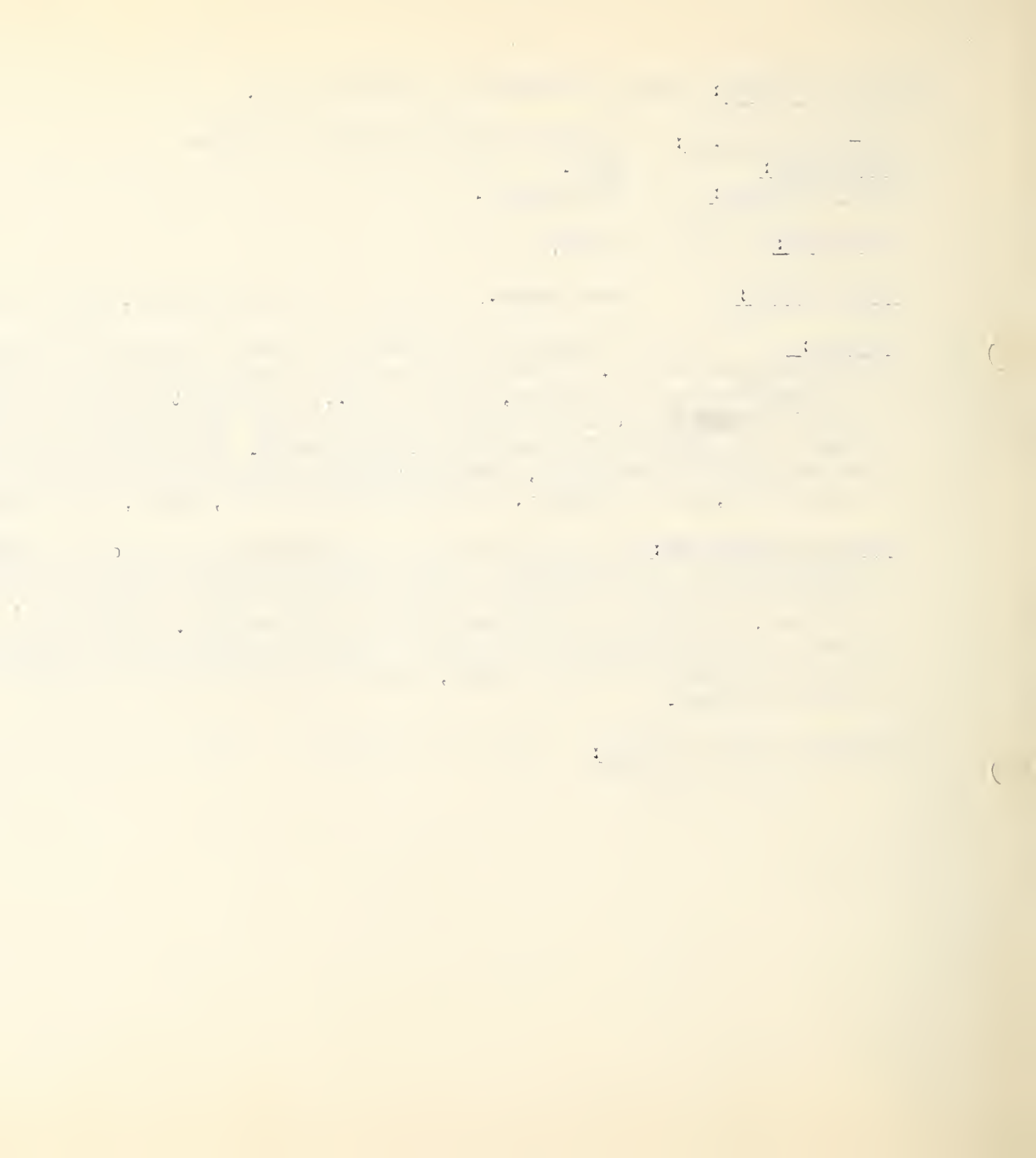
Authority: (Ibid)

Cost of work: Has varied. At present approximately \$1,500 per annum.

Results: A method of controlling floods of mountain streams has been developed and installed on 20 streams in Utah. This method consists of the construction of barriers so designed and located as to check the flow of boulders, gravel, etc., and deposit them upon pre-determined locations. The removal of such boulders and stones from the floods resulting from torrential summer rains makes the flood water available for use in irrigation works. While the work of flood control to date has been planned for Utah conditions, the information developed will be applicable wherever torrential floods carry debris, as for example, in southern California, Idaho, and parts of Texas.

Economic importance: This project is of tremendous importance to people in those areas where torrential rains result in floods carrying large amounts of debris which might wipe out their entire life's savings and the work of years by covering their lands with debris or, as has been the case in many instances, destroying their homes and farm improvements. The removal of boulders and gravel from the flood waters before they are allowed to enter into the drainage canals, as is the case with the control method effected under this project, removes the necessity of cleaning out the irrigation channels after each flood.

Estimated annual savings: No data is available on which to base savings due to above work.



BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF IRRIGATION

13

Title of project: Customs, Regulations, and Laws Relating to Irrigation.
Date begun: 1920.
Date Completed: In progress.

Authority: That part of the appropriation act for the Bureau of Agricultural Engineering, as follows:
"for investigations, experiments, and demonstrations involving the application of engineering principles to agriculture****the customs, regulations, and laws affecting irrigation."

Sub-project no. 1: Financial Rehabilitation of Irrigation Enterprises.
Date begun: 1930
Date Completed: In progress.

Authority: (Ibid).

Cost of Work: Has varied. \$4,000 for 1933.

Results: Studies have been made of a number of irrigation enterprises which were in financial difficulties. These studies have covered the agricultural, economic, and engineering phases of each enterprise and have developed information which has been used as a basis in rehabilitating the financial structure of the enterprises. Recommended plans of financial rehabilitation have been worked out for the Warm Springs, Baker, Beaver Point, Ochoco, Grants Pass, Talent, Medford, Deshutes, Vonnoy, Lone Pine, Silver Lake, Summer Lake, Payette, Oregon Slope, Richland, and Jefferson water conservation districts in Oregon, and the San Pedro Water Users Association in Arizona. The principles of such rehabilitation work which have been developed by this project are applicable to any irrigation district.

Economic Importance: Many irrigation enterprises were undertaken during and immediately following the World War and in most cases these projects were not established on a sound financial basis. With the present unfavorable agricultural conditions, the inability of the land owners to pay their assessments increased, and a very large percentage of the irrigation enterprises of the Western States are now in financial straits. By means of this project method of determining the earning power of the land has been worked out which has enabled a number of districts to re-establish themselves upon the sound principle that assessments cannot exceed the earning principle that assessments cannot exceed the earning power of the land. The fact that a number of districts have re-established themselves through the working out of this project will doubtless have a decided effect in the reorganization of distressed irrigation districts in all sections of the country.

Estimated Annual Savings: It is impossible to estimate the annual savings resulting from work on this project. No similar work is being carried on by the State experiment stations.

Title of project: Customs, Regulations, and Laws Relating to Irrigation, (Cont'd).

Sub-project no. 2: Policies Governing Ownership of Return Waters from Irrigation.

Date begun: 1933.

Date Completed: In progress. To be completed during fiscal year 1933.

Authority: (Ibid).

Cost of Work: 1933 - \$3,600.

Results: Information has been secured upon the legal and practical phases of the acquisition of return waters for irrigation purposes, their extent, value, character of use, and their effect upon irrigation development. The objective for the fiscal year 1933 is the preparation of a bulletin for the information of those engaged in formulating and administering policies governing the control of return waters.

Economic Importance: This is a new sub-project involving the study of public versus private ownership of waters returning to a stream after having been used for irrigation. Only a part of the water applied to irrigated land is actually consumed in the growth of plants. The balance passes through or over the soil and much of it enters natural or artificial drainage channels from which it may again be diverted for irrigation purposes. The legal status of such return waters has been the subject of many controversies in all States where irrigation is extensively practiced.

Estimated Annual Savings: None. No similar work is being carried on by State experiment stations.

Title of project: Customs, Regulations, and Laws Relating to Irrigation. (Cont'd)

Sub-project no. 3: Reorganization, Financing and Consolidation of Irrigation Enterprises.

Date begun: 1920.

Date completed: In progress.

Authority: (Ibid)

Cost of Work: Has varied. For 1933, \$2,400.

Results: Work under this project has developed the fact that considerable savings in the amount of irrigation water used and in the cost of administration can be made by consolidating irrigation enterprises which have parallel canals and obtain their water from the same source. In extreme cases such parallel ditches and canals lose as much as 75 per cent of their initial volume in transit. This project has demonstrated that such waste can be overcome to a great extent by a consolidation of the irrigation systems.

Economic Importance: In the development of the West the low lands along mountain streams were placed under irrigation first thereby acquiring primary water rights. Secondary rights cover lands next higher and so on. In this way a series of canals, many of them more or less parallel, the least and most difficult of construction covering the higher lands which were entitled to surplus water only. Thus the lands which require most water for profitable farming are often entitled to the least amount of water per acre while the lower lands are often waterlogged by seepage from parallel intake canals. Consolidation of such adjoining or parallel districts has been shown to be an economical and practical method of decreasing the cost of irrigation.

Estimated Annual Savings: No estimate can be made of the amount of annual savings. Similar work is not being done by any State experiment station.

BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

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Title of project: Run-off and hydraulics of drainage channels.
Date begun: 1913.
Date completed: In progress.

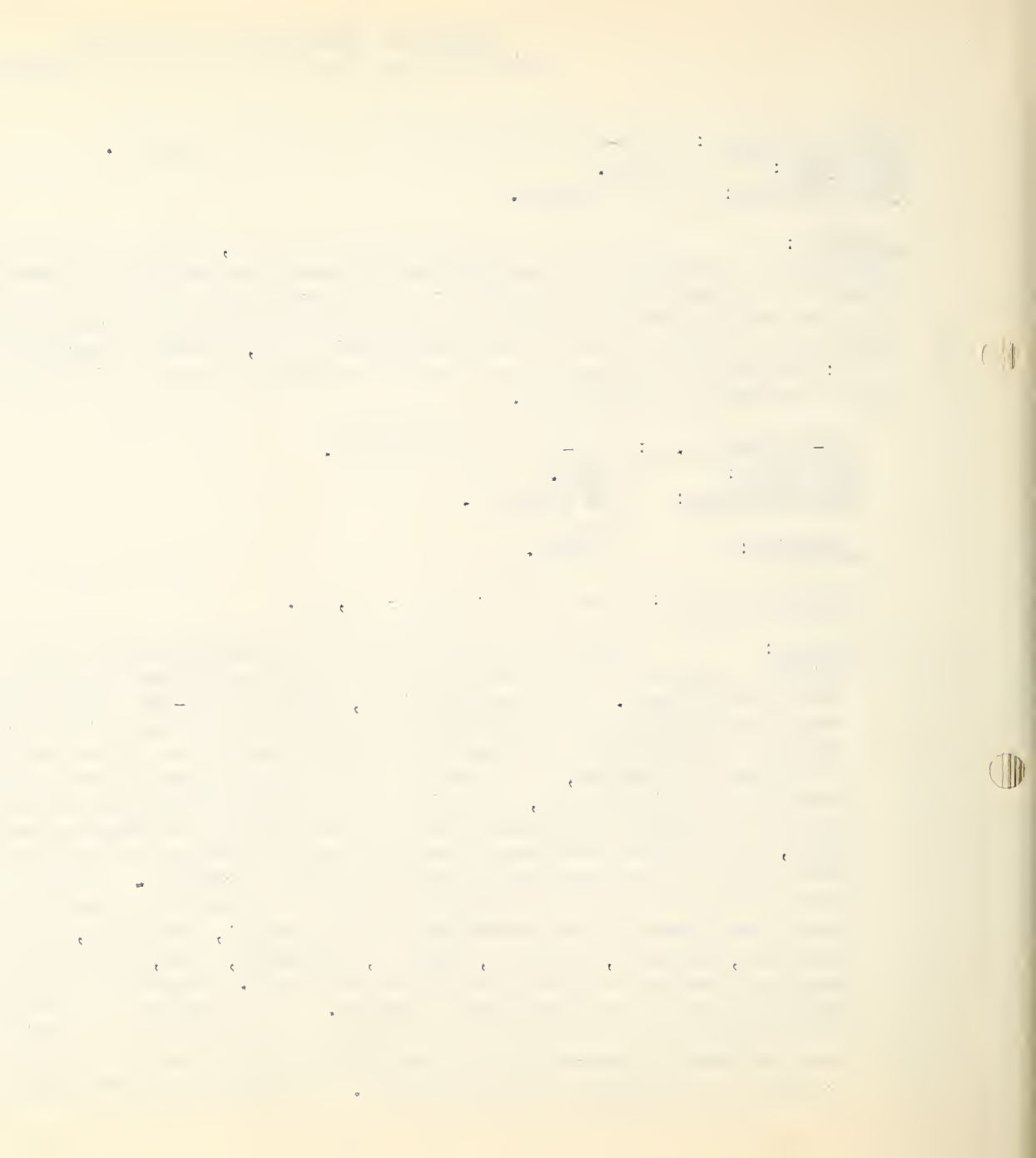
Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows: "For investigating and reporting upon farm drainage and upon the drainage of swamp and other wet land which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage; for the development of equipment for farm irrigation and drainage and for giving expert advice and assistance" and that part of the Appropriation Act, Bureau of Agricultural Engineering, as follows: "***; for preparing plans for the removal of surplus water by drainage; for developing equipment for farm irrigation and drainage".

Sub-project no. 1: Run-off investigations.
Date begun: 1913.
Date completed: In progress.

Authority: (Ibid).

Cost of the work: Has varied; 1933 - \$6,000.

Results: The ultimate object of this investigation is to determine the necessary capacities of open ditches and tile drains for the drainage of land for agriculture in various sections of the United States. To accomplish this, rates of run-off from watersheds of various shapes and sizes are measured and the effect of various influences that retard the flow of water in open channels are measured to determine more accurately the values of the empirical coefficients used in hydraulic formulas, or to devise a new formula should that be more practical. Prior to the starting of this project, a little reliable information was available upon which to base the design of drainage improvements and this was based upon haphazard estimates and guesses. As a result, such improvements were frequently unsatisfactory due to lack of capacity, or else money was wasted in constructing drains larger than necessary. Investigations have been conducted on about 100 watersheds varying in size from a few acres to several thousand square miles. Measurements have been made on watersheds in Mississippi, Tennessee, Alabama, North Carolina, Florida, Arkansas, Missouri, Illinois, Indiana, Minnesota, Iowa, and Ohio and are being conducted at the present time in the last three States mentioned. The results obtained have been published in bulletin form or as mimeographed reports. It is planned to continue the work so as to include all sections of the country where drainage improvements are required. This extension is necessary as rates of run-off vary materially in various sections of the country due to variations in rainfall and watershed characteristics. In addition to data relating to run-off, a knowledge



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Title of project: Run-off and hydraulics of drainage channels (continued).

Sub-project no. 1: Run-off investigations (continued).

of the discharge capacity of a drainage channel is essential to the satisfactory and economical design of drainage improvements. The capacity is affected by all conditions in the channel that retard the flow, as degree of roughness and irregularities in the channel, the growth of vegetation, and the presence of other obstructions to flow. Measurements have been made on over one hundred channels for a wide variety of conditions and the results have been made available as Technical Bulletin No. 129. The results show: that the clearing out of a long-neglected ditch will, in some cases, increase its capacity as much as four times and often provide satisfactory drainage and prevent injurious overflows; that the costly mistake of enlarging a ditch is frequently made when simply cleaning the ditch would produce the desired result.

Economic importance: The design of most of the important drainage improvements constructed since 1915 has been largely based upon the results secured under this project. In the flood control program on the Mississippi River and its tributaries, the results secured on this project have been used as the basis of design for the floodways under construction and proposed. Recent text books on drainage engineering use the results obtained as a basis for recommendations relating to rates of run-off for different sections of the country, and in suggesting values for empirical figures used in hydraulic formulas. In short, the information developed furnishes a basis for the design of any new drainage developments and the maintenance and improvement of the more than 193,000 miles of ditches and tile drains in organized drainage enterprises in addition to the thousands of miles of farm drains.

Estimated annual saving: The savings to be accomplished by the intelligent application of the results of our work are from two sources: first, the prevention of partial, or even total, loss of funds expended due to inadequacy of the improvements; second, unnecessary expenditures involved in providing drainage channels of too large capacity. An idea of the possible savings along this line can be had when it is realized that the difference in cost between a 24-inch and 30-inch tile drain complete is about \$6,000 per mile.

No work is being carried on by State Experiment Stations along this line.

Sub-project no. 2: Cost of pumping for drainage.

Date begun: 1925.

Date completed: Principal work completed in 1932. Plan to continue obtaining records of pumping operations for the drainage pumping plants along the Mississippi River affected by proposed 9 foot channel. This will require three or four weeks work each year by an engineer.

Authority: (Ibid).

Cost of the work: Has varied - 1933, \$5,000.

Results: Prior to the taking up of this investigation there was no reliable data showing comparative cost of using different types of power for pumping for drainage, and drainage district officials depended upon those interested in the sale of different types of machinery for their information relating to operating costs. As a result a number of districts installed one type of power only to become dissatisfied with the cost of pumping and change to another type with the resultant loss of investment. During the years 1925-1932 studies of the cost of pumping for drainage in the upper Mississippi Valley were conducted on 17 pumping plants. These plants were selected as representative of the 63 organized drainage districts in the upper Mississippi Valley operating pumping plants which drain a total of about 450,000 acres of river bottom land. The primary purpose of the study was to determine the economy of different types of power and practical means of reducing the cost of pumping. One bulletin on the cost of pumping for drainage has been published and the manuscript for another bulletin on the design of drainage pumping plants has been completed. In connection with the design bulletin, an important result has been the development of a formula for determining the run-off that must be provided for in designing drainage pumping plants in the upper Mississippi Valley. Both bulletins will find large use by engineers and drainage district officials in planning the rehabilitation of numerous drainage districts now in financial difficulties. An analysis of the data obtained indicates that where dams affect the river stage the amount of pumping required to adequately drain the land is materially increased by seepage. The problem is now of vital importance to districts along the Mississippi River as a result of the dams to be constructed in connection with the nine-foot navigation channel from St. Paul, Minnesota, to St. Louis, Missouri. It is planned to continue obtaining records of pumping operations on drainage districts along this region with a view to having data available for use in determining the effect of backwater resulting from the navigation dams.



Title of project: Run-off and hydraulics of drainage channels (continued).

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Sub-project no. 2: Cost of pumping for drainage (continued).

Economic importance: According to the 1930 Census report, there are 292 drainage pumping districts in the United States affording drainage for 2,175,000 acres. A total of approximately \$110,000,000 has been invested in these enterprises. The application of the results of these investigations to some of the pumping plants upon which tests were made has resulted in decreasing the cost of pumping by from 10 per cent to 40 per cent. Many of the pumping plants are worn out or obsolete and will have to be replaced if satisfactory drainage is to be maintained. The results secured by this investigation furnishes data for use in planning efficient replacements.

Estimated annual saving: It has been found that a large annual saving could be made at practically every plant studied by improving the speed regulations of the pumps. At one plant the decrease amounted to about \$2,000 per annum. It is conservatively estimated that economies by pumping districts in the upper Mississippi Valley have already reached \$50,000 annually as the result of this investigation and that an ultimate saving of approximately \$400,000 annually can be secured through improved pumping efficiency by drainage enterprises in the United States.

No State experiment stations are doing comparable work.

Title of project: Run-off and hydraulics of drainage channels (continued).

20

Sub-project no. 3: Flow around channel bends and pier noses.

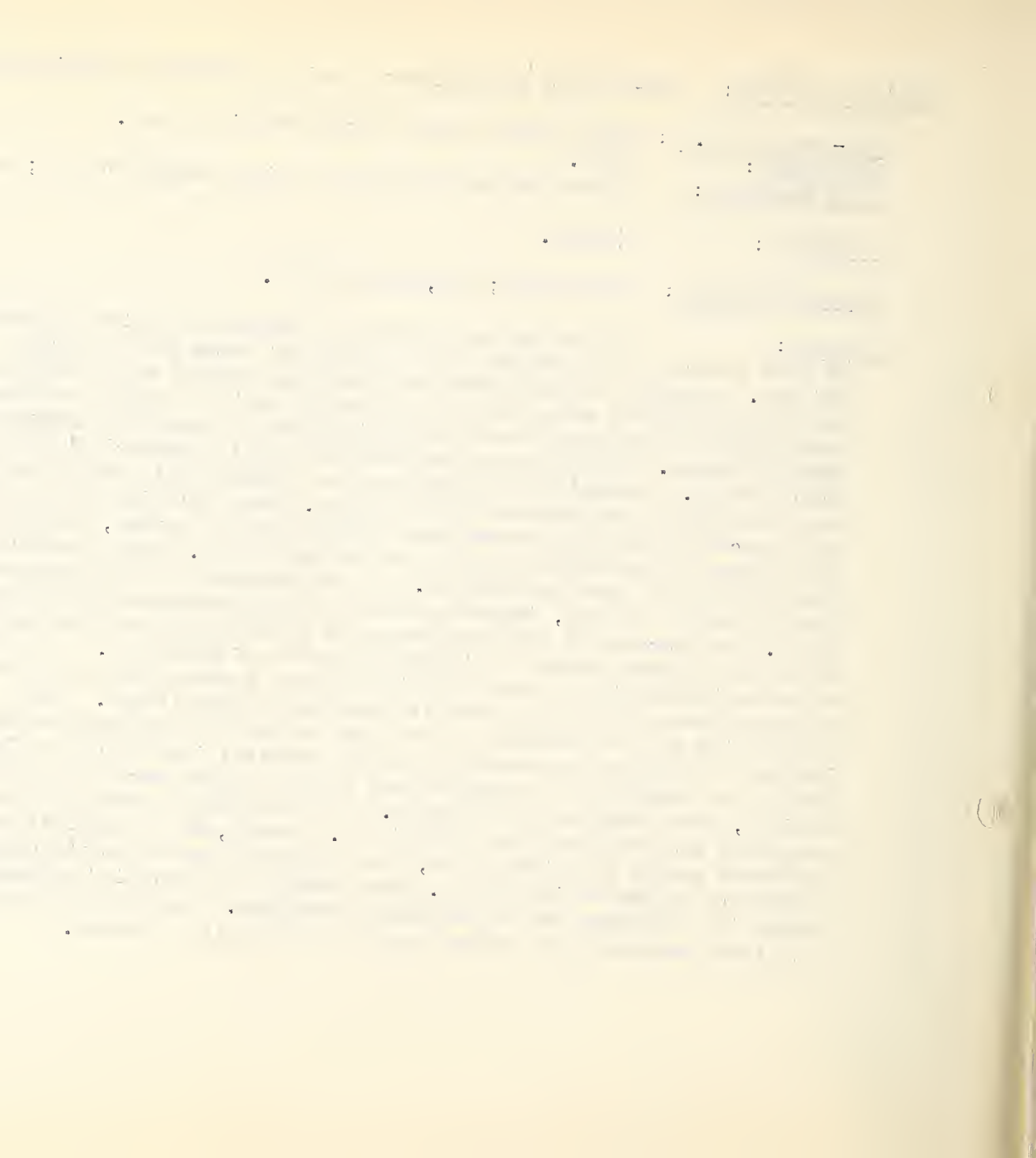
Date begun: 1927.

Date completed: Investigations relating to piers completed 1932; work on channel bends in progress

Authority: (Ibid).

Cost of the work: Has varied; \$13,000 for 1933.

Results: In designing drainage and flood protection improvements it is of vital importance to have accurate information on the effects of bends and of bridge piers and trestles upon flood heights. A poorly designed bend in a drainage channel may result in serious erosion at the bend and raise the flood stage at the bend sufficiently to cause overflow. On natural streams it is important to understand the effect of the bend in order that proper steps may be taken to protect against damage. Bridge piers and trestles tend to obstruct flow in streams, especially during flood stages. Excessive restriction of the channel materially increases the flood stage above the obstruction and increases flood hazard. Data relative to the effect of such obstructions are especially important where land is protected by levees, the heights of which are based upon the maximum flood heights anticipated in the stream. Many disastrous levee failures have resulted from the lack of such information. In cooperation with the Institute of Hydraulic Research of the University of Iowa, investigations are being conducted relating to the flow of water around bends. The purpose of the experiments is to determine the laws controlling the behavior of water as it flows around bends of different degrees of curvature. The results to date reveal much valuable information of use in designing open ditches and pipes but additional information is required before definite hydraulic laws can be established. The investigations relating to the obstruction of pile trestles to the flow of water in drainage channels have developed facts relating to backwater effects that are of practical importance in planning drainage improvements. Methods of constructing trestles have been revealed whereby backwater can be reduced to a minimum, thus reducing flood hazard. A final report covering this phase of the work has been completed and submitted for publication. Some 2,900 experiments have been conducted on eleven different shapes of bridge piers, the purpose of which was the determination of the hydraulic efficiency of the various piers. The results have revealed hydraulically efficient piers which reduce the backwater due to contracted openings. The tests relating to this phase of the project have been completed and a final report is now being prepared.



Title of project: Run-off and hydraulics of drainage channels (continued).

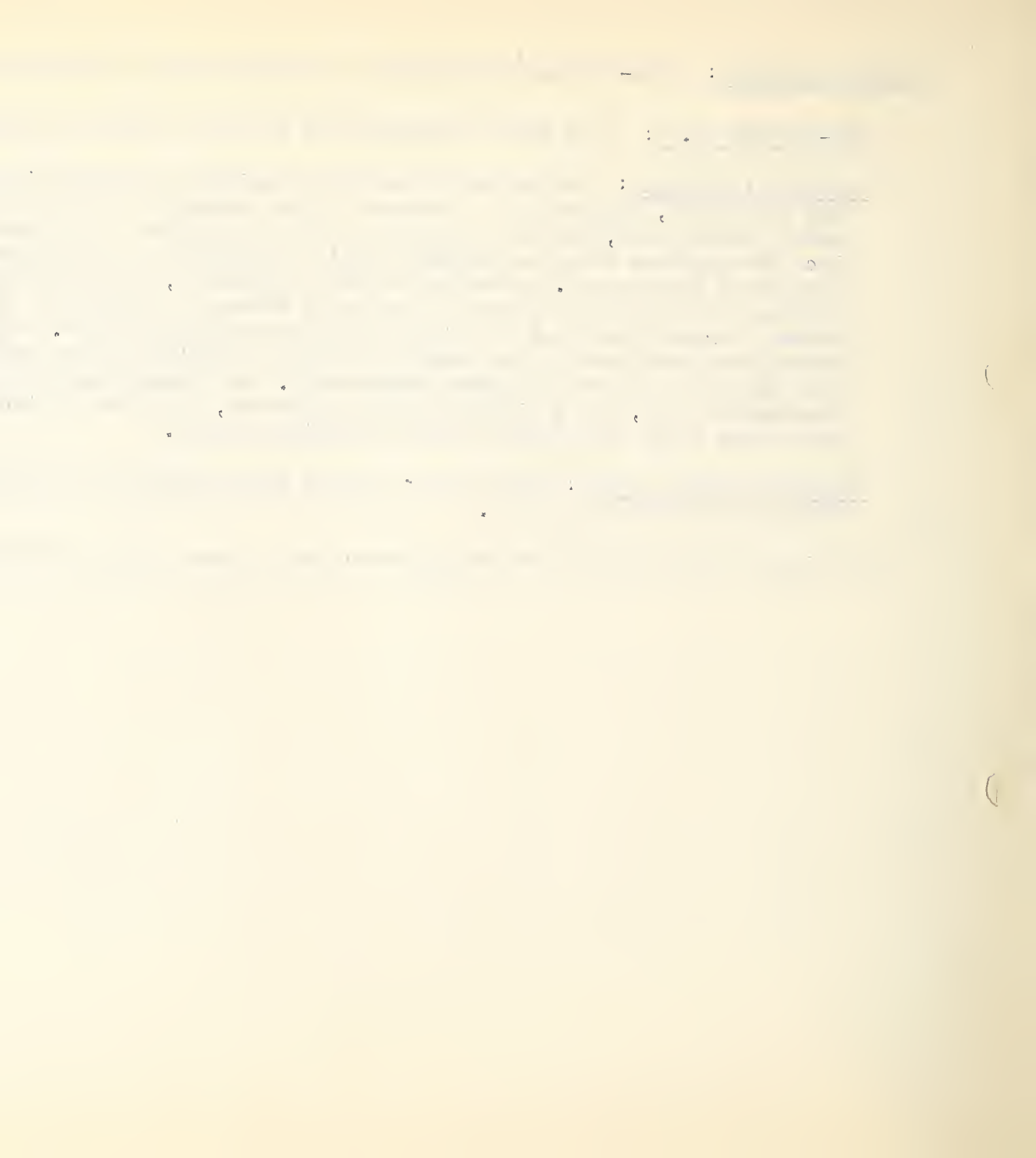
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Sub-project no. 3: Flow around channel bends and pier noses (continued).

Economic importance: The efficient design of drainage and irrigation channels, both open ditches and pipe lines, depends upon a thorough understanding of the hydraulic laws governing the flow of water around bends, and the obstruction offered to flow by pile trestles and bridge piers. The lack of such data explains the many poorly designed and unsatisfactory improvements existing throughout the country. According to the 1930 Census, there are more than 138,000 miles of ditches in drainage districts in the United States in addition to the thousands of miles of natural streams that must be bridged by highways and railroads. A practical example of the benefits of this work is the results obtained in testing one of the standard bridge pier designs used by one of the state highway departments. As a result of the tests, changes in design were recommended that, for a given amount of backwater, permitted a discharge of 14 per cent more water than could be obtained with the original design.

Estimated annual saving: There are no actual data available on which could be computed the annual saving due to the above work.

No similar investigations are being conducted by State Experiment Stations.



BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

22

Title of project: Drainage of farm lands.
Date begun: 1905.
Date completed: In progress.

Authority: That part of the Appropriation Act, Bureau of Agricultural Engineering, as follows: " x x x for preparing plans for the removal of surplus water by drainage; for developing equipment for farm irrigation and drainage;"

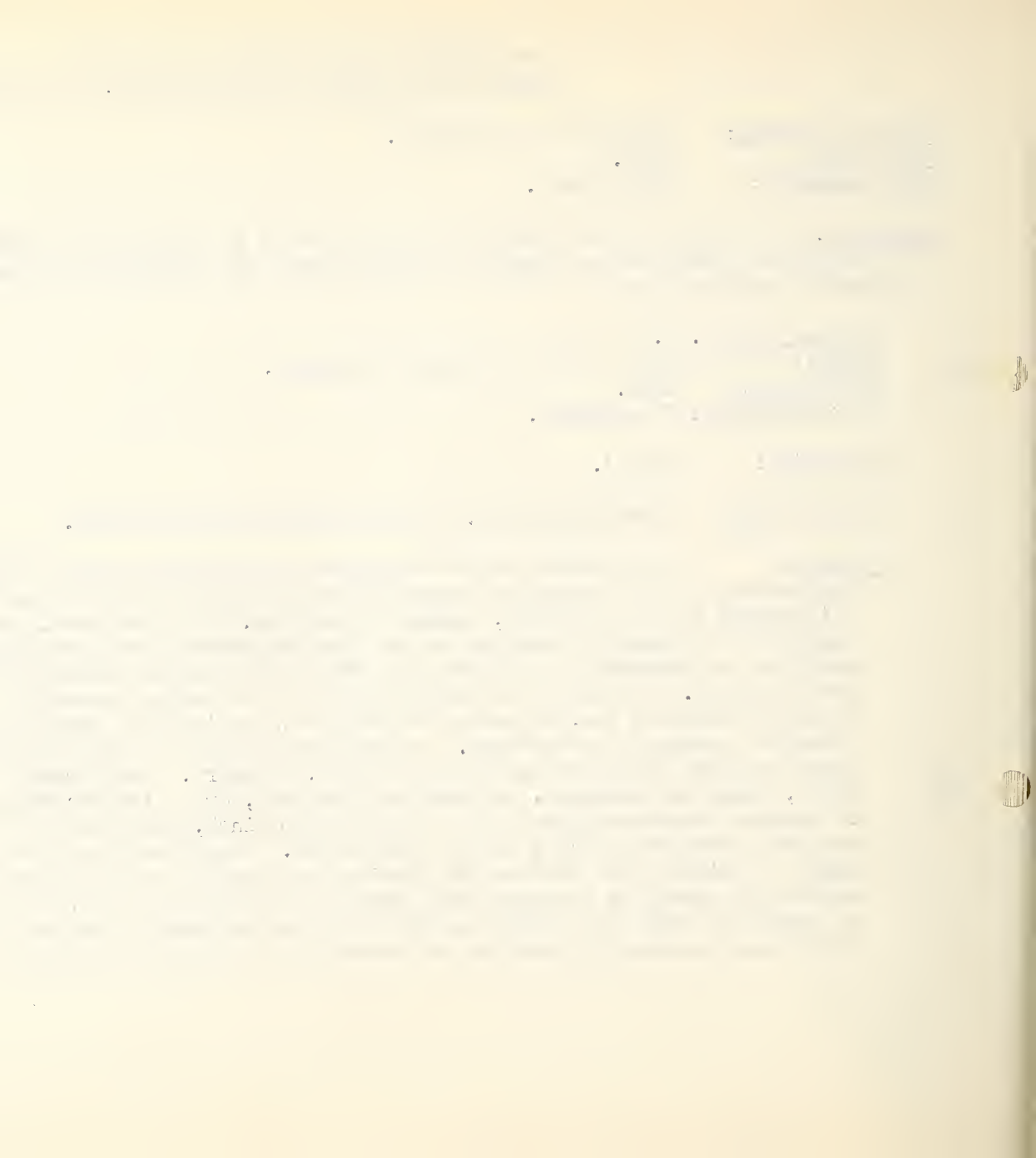
Sub-project no. 1.

Title: Maintenance of drainage channels.
Date begun: 1931.
Date completed: In progress.

Authority: (Ibid).

Cost of work: Approximately \$3,500 per annum from Bureau funds.

Results: Investigations have developed the fact that proper maintenance is essential if drainage channels are to retain the capacity for which they were designed. Measurements show that where maintenance is not practiced, channel capacities, in a few years, are frequently reduced to less than half the capacity existing at the time the channel was constructed. This results in poor drainage and frequent loss of crops in areas where large expenditures have been made to obtain good drainage. The purpose of this project is to develop economical methods of maintaining channels so that landowners can, by proper maintenance, receive full benefit from the funds expended in constructing drainage improvements. In cooperation with the State Highway Department of Delaware, investigations are under way in Kent County, Delaware. Experiments are being conducted with hand labor, teams and scrapers, tractors and scrapers, drag line excavators, and explosives. A method of using a tractor equipped with a double drum winch, pull and haul back lines and two scrapers has been developed which is proving efficient. Experiments are also being conducted with various kinds of poisons with the hope of finding one harmless to livestock and which will yet kill the vegetative growth in channels after they have been cleaned out. The work in Kent County is limited to sandy and sandy loam soils and will later be expanded to include ditches in clay and clay loam soils where excavating problems are essentially different from those involved in handling sandy soils.



Economic importance: The Bureau of the Census shows that there are more than 138,000 miles of open ditches in organized drainage enterprises in addition to the thousands of miles of ditches on individual farms. During the past few years these ditches have, due to general conditions, been greatly neglected and as a result practically all of them are sadly in need of maintenance. In many instances ditch capacities have been reduced to such an extent that satisfactory drainage can no longer be obtained and time and money is being expended in cultivating formerly well drained areas only to lose crops as a result of poor drainage.

Estimated annual saving: There is no reliable data available upon which to base an estimate of the annual loss resulting from the failure to maintain existing drainage ditches. It is conservatively estimated that fully 75 per cent of such improvements are in immediate need of maintenance.

There are no records of state agricultural experiment stations conducting similar investigations.



Title of project: Drainage of farm lands. (Continued)

Sub-project No. 2.

Title: Effect of soil alkalies, soil acids and frost on clay and concrete tile.

Date begun: 1921.

Date completed: Not completed. Estimated that alkali phase will be practically completed in 1933.

Authority: (Ibid)

Cost of work: Approximately \$5,000 per annum of Bureau funds.

Results: Prior to 1921 there occurred in Minnesota very extensive failures of concrete drain tile installed. These failures were due to disintegration and resulted in very great losses. In 1921, in cooperation with the University of Minnesota and the State Department of Drainage and Waters, this Bureau began investigations which had as their object - first, determination of the cause of the failure of concrete tile. Second, the development, if possible, of concrete tile which would withstand the action of soil alkalies and soil acids. Third, to determine those areas where commercial concrete tile can be safely used. A laboratory was cooperatively established at University Farm, St. Paul, Minnesota, with funds made available by an appropriation of the Minnesota State Legislature. Since that time more than 50,000 concrete samples of various kinds have been exposed to sulphate action for periods of from 3 to 8 years with a view to developing some method of making concrete so that it will be impervious to such action. Methods of measuring the resistance of concrete to sulphate action have been developed and it has been determined that highly resistant concrete tile can be made by steam curing when 12 to 24 hours old at temperatures of 212°F. or higher for 48 hours or longer. The problem of developing commercial methods of steam curing at such high temperatures is still to be solved. The use of alumina cement in concrete subject to severe conditions of sulphate exposure has been found desirable and favorable results have been obtained with the use of certain admixtures in concrete tile cured at temperatures of 100° to 155°F. This last development appears promising as it is now common practice at many tile plants to use curing temperatures between 100° and 155°F. A manuscript has been prepared and submitted for publication covering the work to date. Future work on this phase of the project will be limited primarily to the testing of concrete samples that have been exposed to sulphate action for periods up to ten years. Examination has been made of numerous installations of drain tile in various acid mineral soils and in peat and muck soils in various sections of the country.



Title of project: Drainage of farm land. (continued)

Sub-project no. 2. (continued).

Evident deleterious action on concrete tile in numerous systems examined indicates a real need for complete information as to the causes and for remedial measures. Work along this line has been in progress since 1925 and a report is now being prepared, the conclusions being based on one, three and five year tests of something over 3,000 samples representing 86 different groups or mixtures of concrete. The use of poor quality tile, both clay and concrete, in cold climates has been followed, in numerous instances, by losses because of the failure of the tile through frost action. Studies of the effect of frost action on drain tile have been under way since 1925 and the work, as pertaining to Minnesota, was summarized in a mimeographed progress report. The results obtained have made it possible, within practical limits, to predict from the results of standard absorption tests, the frost resistance of tile. However, such tests require a great deal of time and it is planned to undertake to correlate the results obtained with those produced by action of crystallization when stored in solutions of sodium sulphate, the object being to discover the limitations in reliability of such procedure as an accelerated test.

Economic importance: In Minnesota alone there are more than 7,000 miles of public tile drains that already have cost \$10,000,000 and several times this amount will eventually be required in the agricultural development of the state. In addition, there are many thousand miles of individual farm drains. No exact figures are available to show the losses that have occurred through the disintegration of drain tile from the action of alkali and soil acids but in Minnesota alone information indicates that such losses amount to hundreds of thousands of dollars. The result of much of this work is of value to those western states having alkali areas to be drained, and to the Atlantic coast states having large areas of peat and muck soils and acid soils; also much of the work will apply to conditions in Wisconsin and Michigan.

Estimated annual saving: Authentic data is not available upon which to express in figures the annual saving resulting from this work.

There is no record of similar work being conducted by any of the state experiment stations.

Title of project: Drainage of land.

Sub-project no. 3. Drainage of sugar cane land.

Date begun: 1930

Date completed: In progress.

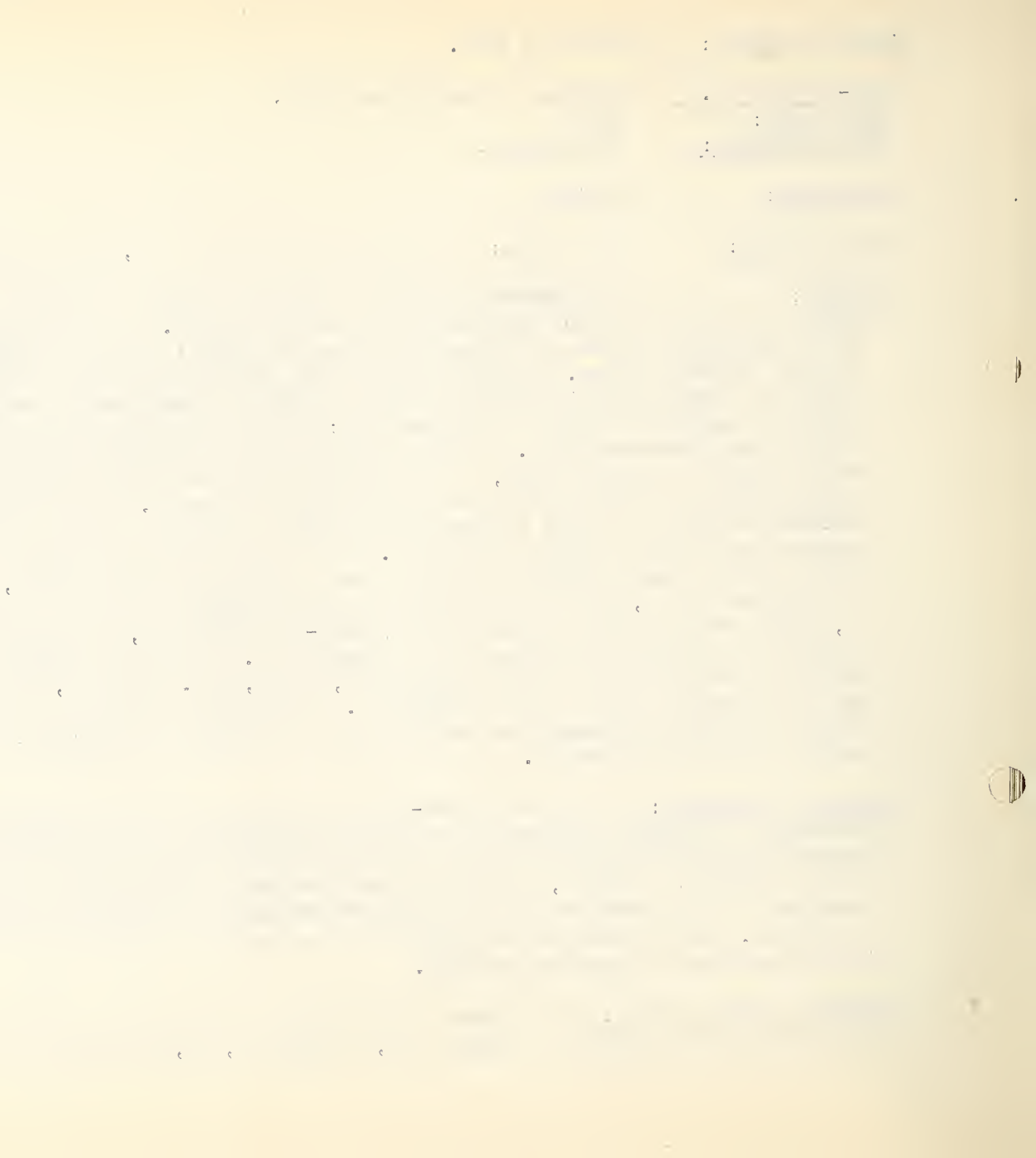
Authority: (Ibid)

Cost of work: Has varied; at present approximately \$6,500 per annum.

Results: The general practice in draining sugar cane land in southern Louisiana is to construct systems of shallow ditches spaced close together. The drainage thus obtained is frequently unsatisfactory and loss of crops due to poor drainage is often a severe handicap to the sugar cane industry in that region. The purposes of this investigation are to determine the effectiveness of deep open ditches and tile drains in the drainage of land growing sugar cane: the most economical depth and spacing for drains for such land; and the practicability of pumping from wells in the drainage of sugar cane land. Owing to the competition of Cuba and the Philippines in the production of sugar from sugar cane, it is essential that the sugar industry in Louisiana produce sugar as economically as possible if the industry is to survive. This investigation indicates that deep thorough drainage not only increases the number of tones of cane grown per acre, but also tends to increase the sugar content of the cane. The records obtained during 1931 show that a second stubble plot of cane (POJ36) drained by deep open ditches produced 1,338 pounds of sugar per acre as compared with 1,018 pounds per acre for a check plot drained in the customary manner. Similarly, a tile drained plot of plant cane (POJ36-M) produced 1,638 pounds of sugar per acre as compared with 849 pounds per acre for the check plot. All this difference may not be due to drainage part of it may be due to borer infestation, stand, etc. However, indications are that drainage was the principal cause of the difference. Records will have to be obtained over a period of years in order to eliminate and control other variables and enable us to determine the economical depth and spacing of drains.

Economic importance: More than three-fourths of the cane sugar produced in the United States is produced in southern Louisiana in the region affected by this investigation. The soil and climate of the region are well suited to the growing of sugar cane and large sums have been invested in the industry. However, if it is to survive foreign competition with its cheap labor, it is essential that the maximum crop possible be obtained for the money expended in labor, seed and fertilizer. The results so far secured on this project indicate that crop yields can be materially increased by improved drainage.

Estimated annual saving: The Bureau of the Census reports that in 1929 approximately 200,000 acres in Louisiana were planted to sugar cane, yielding 2,992,122 tones of cane. The present acreage



Title of project: Drainage of land. (continued).

Sub-project no. 3. (continued)

is practically the same as that for 1929. Indications are that deep drainage, such as is being investigated on this project, will result in an increased annual yield of cane from the same land of at least 10 or 15 per cent. The experimental areas showed an increase of from 20 to 40 per cent in yield from deep drained land over land drained according to generally followed practices.

Title of project: Drainage of land.

Sub-project No. 4:

Title: Groundwater studies in Florida.

Date begun: 1932.

Date completed: In progress.

Authority: (Ibid)

Cost of work: Approximately \$4,000 per annum.

Results: Recent investigations by the Florida State Agricultural Experiment Station indicate that the agricultural value of peat and muck soils is dependent, to a great extent, upon the elevation of the groundwater table. Profitable crop production has been obtained on peat and muck areas where the depth of the groundwater is fairly uniform, while in localities with wide fluctuations of groundwater, frequent crop failures have occurred. The ultimate object of this project, which is being undertaken in cooperation with the Florida Experiment Station, is to determine the effect of controlling groundwater elevation upon the productivity of peat and muck soils of Florida. The results obtained will be applicable to other areas of peat and muck soils in other southern states where climatic conditions compare with those of Florida. The project has not been in operation a sufficient length of time to obtain any definite results. An area has been established on the Everglades Experiment Station in which the groundwater can be controlled by ditches and underdrains. A pump has been installed and so equipped as to pump water from or on to the area as conditions may require to maintain the desired groundwater elevations. Crops suitable to the soil and region will be grown and from the growth and yield obtained the optimum elevation of the water table to be maintained for various peat and muck soils in the semi-tropical regions of the south will be determined. Practical methods of controlling the elevation of the water table are being developed.

Economic importance: There are in excess of 2,500,000 acres of peat and muck land in the Florida Everglades which, because of its location, is especially adapted for the growing of winter vegetables and other crops. A considerable area of this land has been drained and its value for crop production is dependent, to a great extent, upon the determination of the optimum depth of groundwater elevation for different crops and upon the development of practical methods of attaining such elevation. The results obtained will be applicable to the large areas of peat and muck lands in southern Louisiana.

Title of project: Drainage of Land (continued).

Sub-project No. 4: (continued).

Estimated annual saving: There is no reliable information upon which to base an estimate of annual saving.

DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

Title of project: Drainage of farm lands. (continued)

Sub-project No. 5: Drainage index of soils.

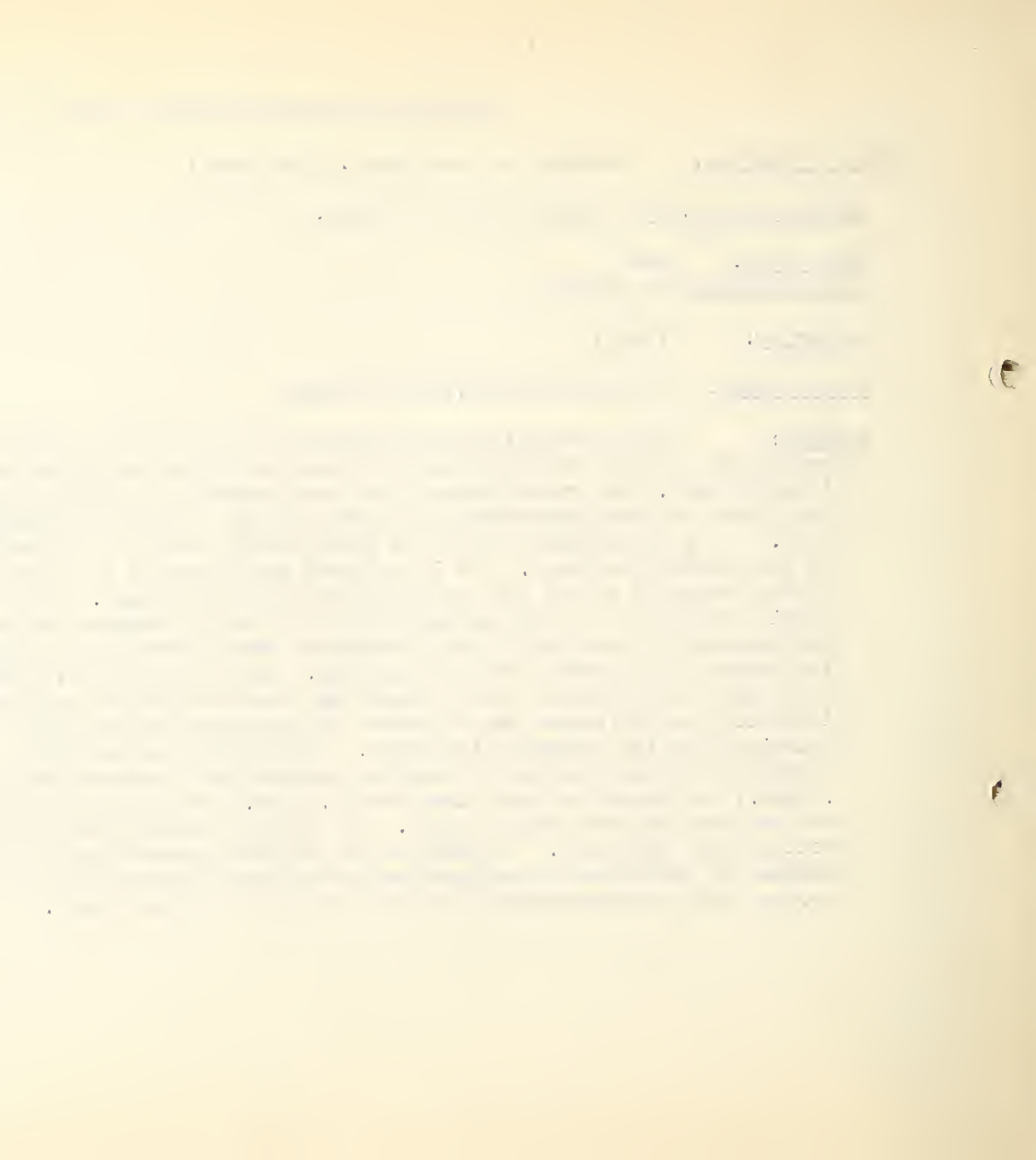
Date begun: 1927

Date completed: In progress

Authority: (Ibid)

Cost of work: Approximately \$3,000 per annum.

Results: This sub-project was undertaken with a view to developing some method that will enable the engineer to determine in advance the proper depth and spacing of drains for various types of soil. At present there is no known method of obtaining such information and the installation of such improvements is usually based upon the judgment of the engineer designing them. If a satisfactory index can be developed it will be a decided step forward in the field of agricultural drainage. It is believed that there is a definite relation between the permeability factor of a soil and its susceptibility to drainage. An attempt has been made to determine whether or not the permeability of a soil is constant by securing soil samples with undisturbed structure and in the laboratory under controlled conditions of water supply determine the permeability factors for such samples. At the same time, additional samples of the same soils have been obtained with an auger and these additional samples have been subjected to laboratory analysis with the object of finding some easily tested property that varied in direct relation with the permeability factor. Investigations have also been made of the possibilities of basing drainage indices for soil on percolation; hygroscopicity; on content of clay less than .002mm.; on elutriable parts less than 0.01 mm.; and on the specific surface of soil particles, but the results have varied widely. A detailed analysis and report of the data thus far collected is under way. If the results indicate possibilities of developing satisfactory indices by additional investigations, such investigations will be undertaken; otherwise the project will be discontinued upon the completion of the report.



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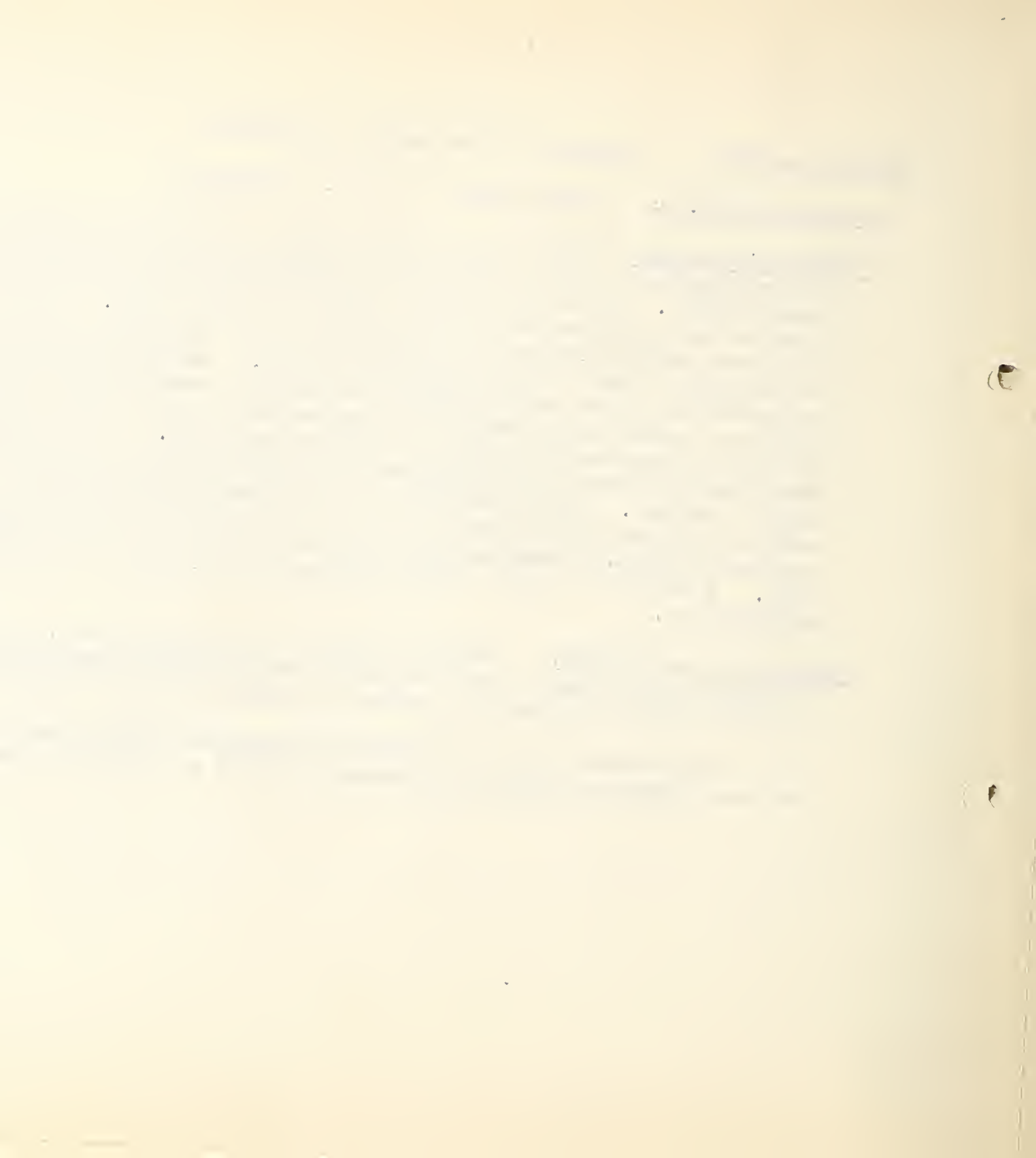
Title of project: Drainage of farm lands. (continued)

Sub-project No. 5: Drainage index of soils. (continued)

Economic importance: There are no exact figures available to show the losses that have occurred through the lack of data relative to the proper depth and spacing for the drains in different types of soil. The 1930 report of the Bureau of the Census shows that more than 44,500,000 acres of farm land has been drained, much of it with tile. The drainage on a large part of this area is not satisfactory, primarily because the drains have improper spacing and depth for the type of soil in which they are placed. Numerous instances have been found in the mid-western states where unsatisfactory results have been secured from tile drains - not because they were spaced too far apart but because they were not placed deep enough in the ground. As a result, poor crop yields are obtained each year. In the coastal plains region of North Carolina many tile drains have been constructed with a spacing of 60 to 70 feet and a depth of 3 feet. An investigation has disclosed the fact that in this particular region the soil is such that tile spaced 100 to 125 feet apart and from 4 to $4\frac{1}{2}$ feet deep affords excellent drainage. This increased spacing reduces the cost of the work approximately 40 per cent. A reliable drainage index would make it possible to obtain satisfactory drainage at minimum cost.

Estimated Annual Saving: Owing to the lack of authentic data, it is not possible to express in figures the annual saving that would result from the development of a reliable drainage index for soils, but there is reason to believe that such saving would be large.

 The Minnesota State Agricultural Experiment Station has done some work relative to the use of rate of percolation through soils as a basis for a drainage index for soils.



DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

Title of project: Drainage of farm lands (continued)

Subproject No. 6: Sewage irrigation

Date begun: 1929

Date completed: Not completed. Expect to discontinue project at the end of the 1933 crop season.

Authority: (Ibid)

Cost of work: Approximately \$3,400 per annum

Results: In many municipalities the disposal of sewage represents a large annual expense and results in the loss of large amounts of fertilizer ingredients of value in producing agricultural crops. The purpose of this investigation is to develop economical methods of using sewage in irrigating agricultural land that can be applied in the humid region of the United States: to determine costs of constructing and operating sewage irrigation plants; and to study the biological aspects of sewage irrigation. In cooperation with the State Agricultural Experiment Station of New Jersey, investigations relating to sewage irrigation are being conducted on a tract of land owned by the Borough of Vineland, New Jersey. Economical methods of distributing sewage to the land have been developed, and satisfactory methods of applying sewage to a large number of different crops have been determined. Large yields of crops have been obtained on the sterile sand common to the Vineland region. As an example, in 1932 the yield of field corn on sewage irrigated land ranged from 52 to 70 bushels per acre as compared with a crop failure on similar unirrigated land that had a heavy application of manure. Similar large yields on irrigated land were obtained with carrots, artichokes, asparagus, alfalfa, eggplant, cabbage, mangles, and sweet potatoes. The State Experiment Station has cooperated by conducting the investigations relating to the biological aspects of the project. Reports from England and Germany state that sewage irrigated crops have been safely consumed in those countries for many years.

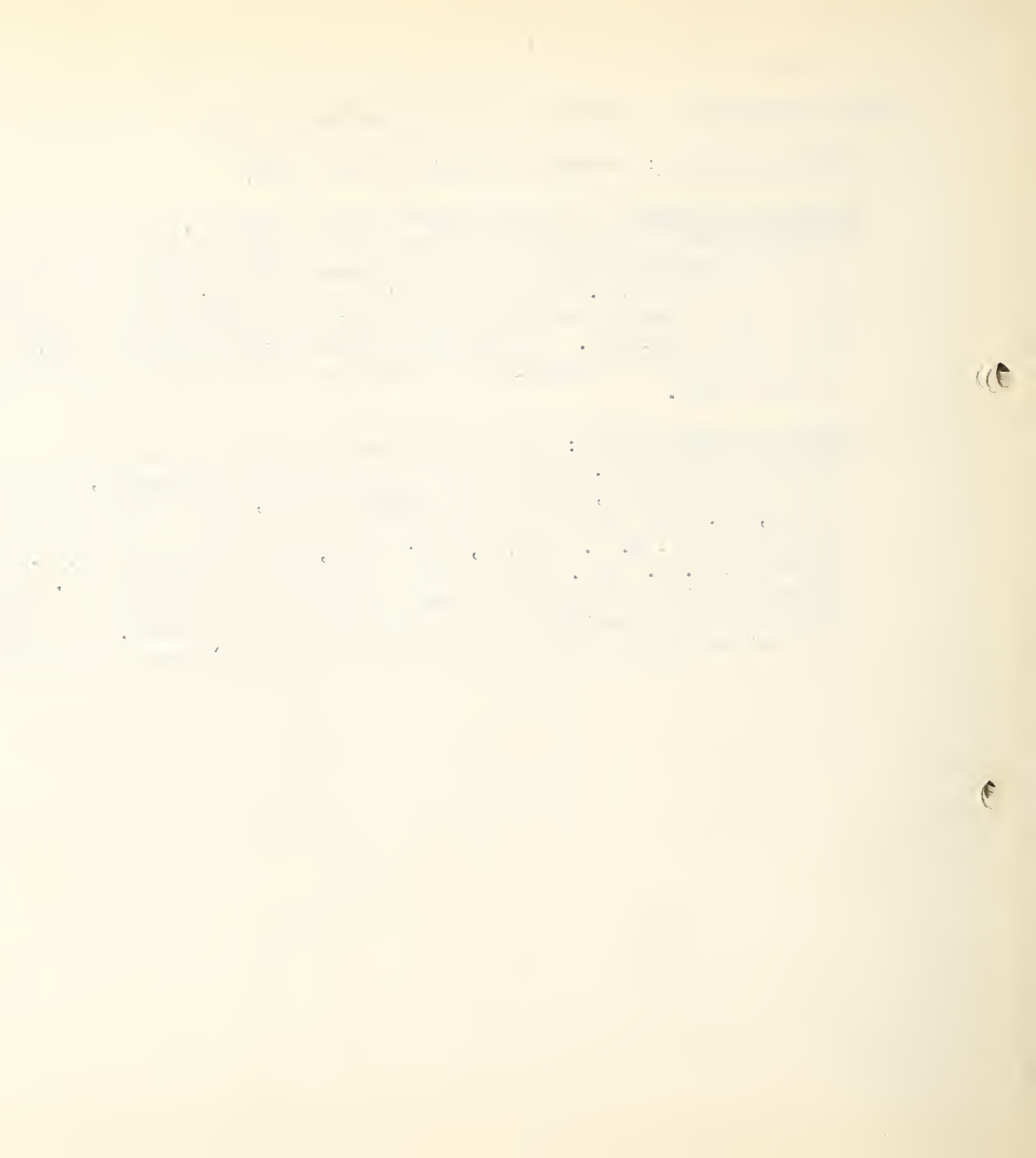


Title of project: Drainage of farm lands (continued)

Subproject No. 6: Sewage irrigation. (continued)

Economic importance: Throughout New Jersey, Delaware, the eastern shore of Maryland, and in many other regions of the humid sections of the country there are areas of infertile land located close to municipalities that can be successfully farmed only by the use of large amounts of commercial fertilizers. The municipalities are spending large sums annually to dispose of sewage that can be used in irrigating and fertilizing this land at a saving to both the municipality and to the landowner. The landowner obtains increased crop yields with decreased expenditure for fertilizers and the municipality disposes of its sewage at decreased cost which should result in reduced taxes.

Estimated annual saving: There is no actual data available upon which to base an estimate of total annual saving. As an example of what can be expected, the cost of sewage disposal to the Borough of Vineland, New Jersey, (population 8,000) by a system of irrigation for the year 1932 was \$1,200. The cost of sewage disposal in the usual manner during 1931 amounted to \$3,000 for Haddon Heights, N. J. (pop. 5,418); to \$4,372 for Haddonfield, N. J. (pop 8,857); to \$2,500 for Glassboro, N. J. (pop. 4,000) and to \$7,000 for Red Bank, N. J. (pop, 9,260). Such figures indicate that if the practice of sewage disposal by irrigation is adopted, where practical, the annual saving to municipalities will total a large amount. In addition, increased returns will be obtained by the farmer as the result of increased crop yield and decreased fertilizer expenses.



BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

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Title of project: Customs, Regulations and Laws Relating to Drainage.
Date begun: 1908
Date Completed: In progress

Authority: That part of the Appropriation Act, Bureau of Agricultural Engineering, as follows:

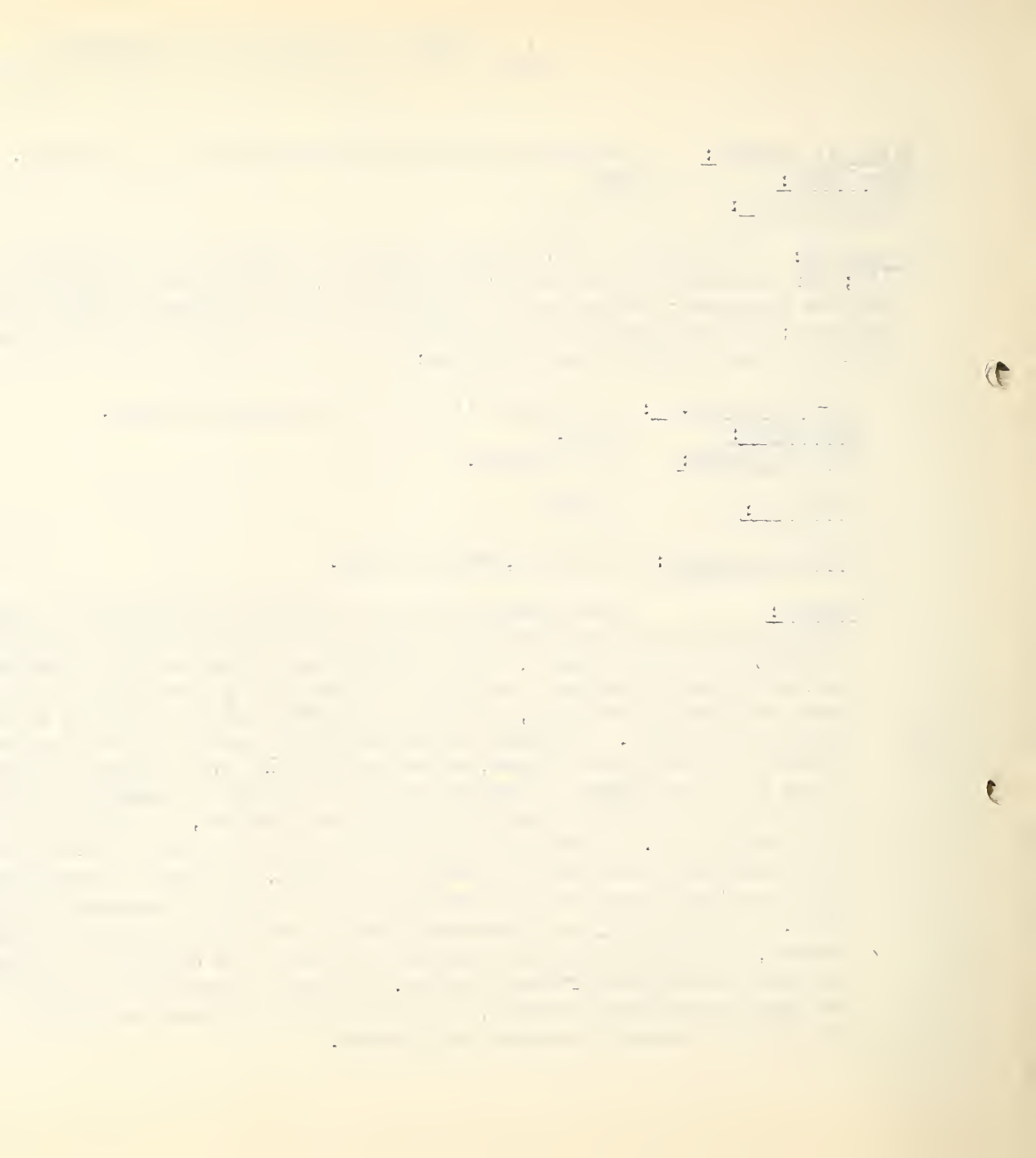
"**; for investigating and reporting upon ***, the customs, regulations and laws affecting irrigation and the drainage of farms and of swamps and other wet lands which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage for the developing of equipment for farm irrigation and drainage;"

Sub-project no. 1: The Rehabilitation of Drainage Districts.
Date begun: 1932.
Date completed: In progress.

Authority: (Ibid)

Cost of the work: 1933, \$5,000 per annum.

Results: The rehabilitation of drainage enterprises in financial difficulties is becoming increasingly important because of numerous defaults in the bonded indebtedness of such districts brought on, in most cases, by the low prices of agricultural products. In many districts funds are not available to properly maintain the drainage improvements and unless steps are promptly taken to work out the difficulties, both the landowner and the investor in drainage securities will lose their entire investment. In numerous districts the amount of the state and county taxes, together with the special drainage assessments, exceed materially the earning capacity of the land. Under such conditions it is obviously impossible for the landowner to meet his taxes. The object of this project is to work out, in cooperation with interested parties, a solution of the difficulties on the ability of the land to pay. Detailed studies will be made of several districts and practical methods developed for determining the earning power of the land, the cost of maintaining drainage improvements, and the amount of district and farm drainage improvements necessary to put the land in profitable condition. A field study has been completed of one of the largest drainage districts in the United States, in which ninety per cent of the land is in default in taxes, and a plan of rehabilitation is being developed for the district. Similar studies will be made of several other districts and as soon as the data warrants, a bulletin will be issued outlining successful plans for rehabilitating and refinancing drainage enterprises.



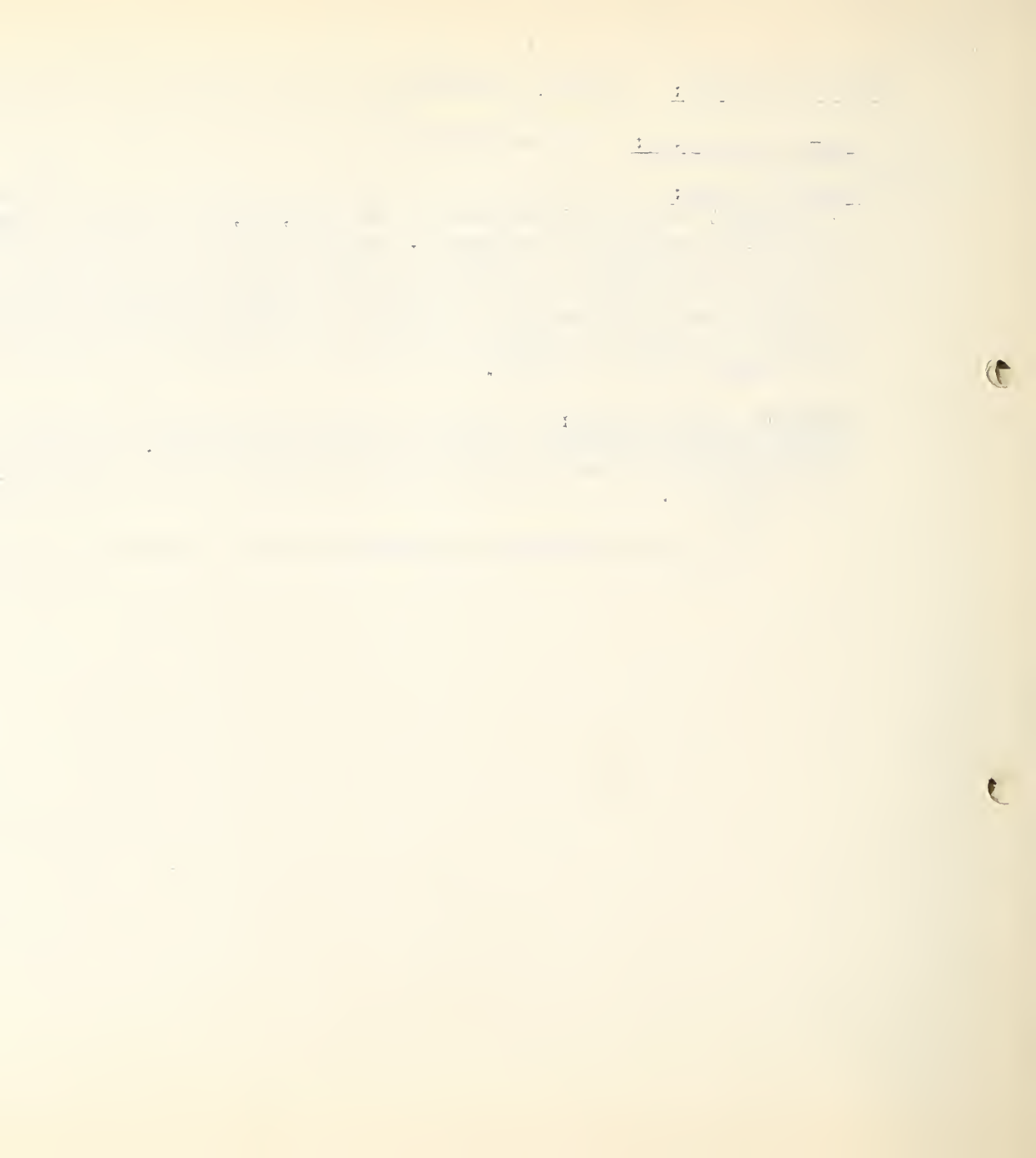
Title of project: Customs, Regulations and Laws Relating to Drainage (continued)

Sub-project no. 1: The Rehabilitation of Drainage Districts (continued)

Economic Value: The Bureau of the Census reports that in 1929 drainage districts with a capital investment totaling 17 per cent of the \$680,732,880 invested in such enterprises were in default on their outstanding indebtedness. Since 1929 it is known that the amount of delinquency has increased materially but there is no accurate data as to the exact amount. Most of the drainage districts in default do not have funds available to maintain their drainage improvements and as a result the productivity of the land is rapidly decreasing because of poor drainage. It is essential that steps toward rehabilitating such districts be promptly taken if a total loss of the investment is to be avoided.

Estimated Annual Saving: There is no reliable data available upon which to base an estimate of the annual saving that will result from this investigation. A satisfactory plan for rehabilitating drainage enterprises will enable many districts to avoid bankruptcy and total loss of investment of landowners.

No state agricultural experiment station is conducting a similar investigation.



Title of project: Customs, Regulations and Laws Relating to Drainage. (continued)

Sub-project no. 2: Drainage District Operation.

Date begun: 1932.

Date completed: In progress

Authority: (Ibid)

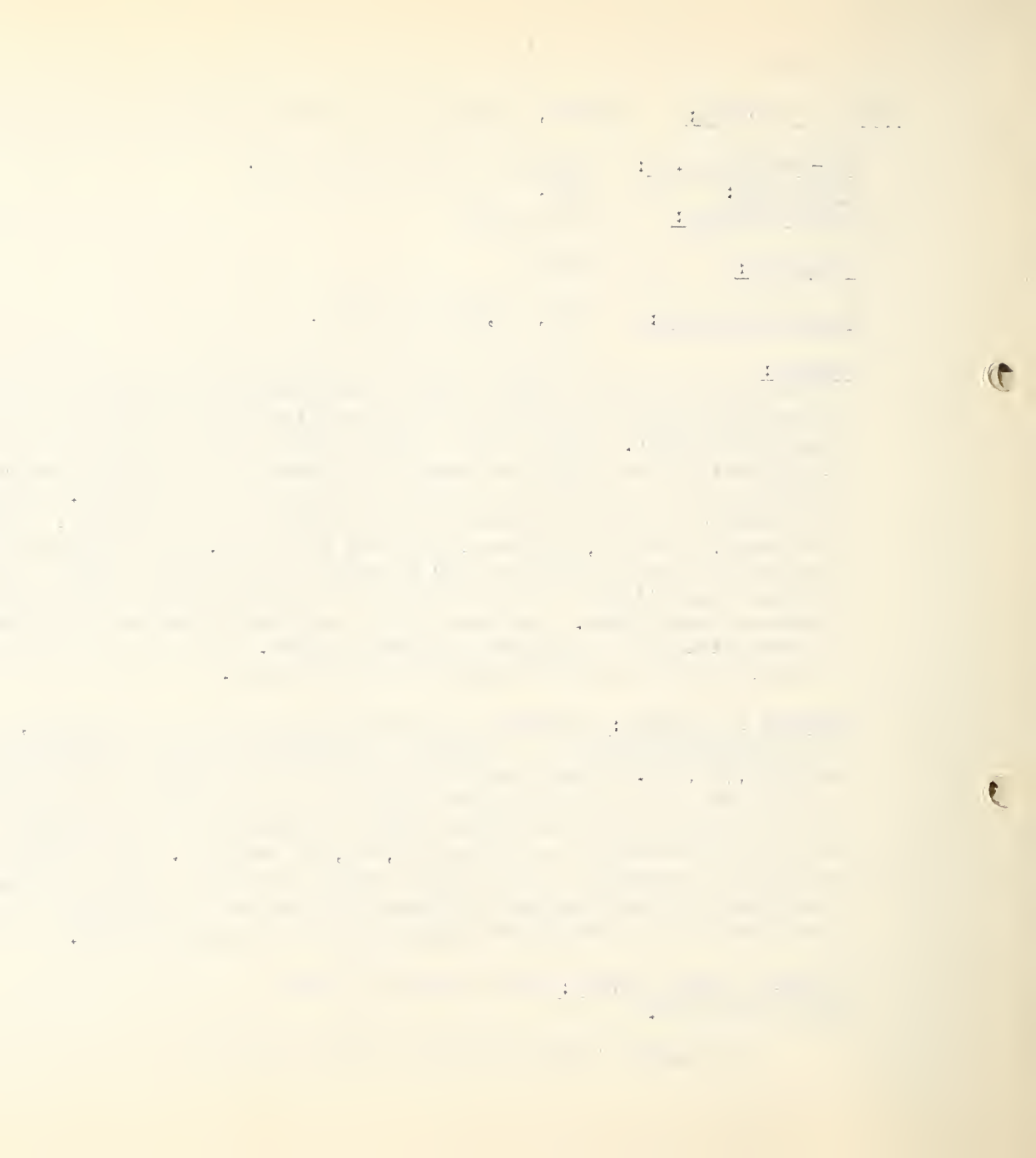
Cost of the work: 1933, \$5,000 per annum.

Results: The purpose of this investigation is to make a broad study of all the operations of drainage districts with a view to determining why some have failed and others prospered, and what effect the various conditions of organization and operation have toward the success or failure of such enterprises. The report of such a study will not only be of value in the management of existing districts but will also serve to discourage the organization of unwise or untimely drainage projects that are certain to result in loss to all concerned. Field studies have been completed on 40 drainage districts located in the states of North Carolina, South Carolina, Georgia, Tennessee, Louisiana, Missouri, Illinois, Iowa and Minnesota. The information obtained indicates that many constructive recommendations can be made for improving methods of handling district affairs and that certain suggestions can be offered for improving laws governing the organization and operation of drainage enterprises. The data so far obtained is now being analyzed and, if the results warrant, a manuscript will be prepared for publication. If the data is not complete enough to warrant publication, additional field work will be undertaken.

Economic Importance: According to the Bureau of the Census (1930), more than 84,400,000 acres of land in the United States are included in organized drainage enterprises with a total capital investment of \$680,732,000. These organizations have a continuing life and their economical management and maintenance vitally affects the welfare of the thousands of landowners who have invested in them. It is estimated that the annual cost of operation and maintenance averages at least 5 per cent of the capital investment or more than \$34,000,000 per year. The work under this project should enable drainage enterprises to materially reduce this large annual expense. Another factor of economic importance is that the data collected will serve to discourage the organization of unwise or untimely projects that are certain to result in loss to all concerned.

Estimated Annual Saving: Data is not available to make an accurate estimate of the annual saving from this work.

No similar investigations are being carried on by the state agricultural experiment stations.



Title of project: Customs, Regulations and Laws Relating to Drainage (continued)

Sub-project no. 3: Drainage District Organization, Administration and Development.

Date begun: 1908.

Date completed: Work was conducted intermittently. Project closed 1923.

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows:

"For investigating and reporting upon farm drainage and upon the drainage of swamp and other wet lands which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage; for the development of equipment for farm irrigation and drainage and for giving expert advice and assistance; for field experiments and investigations and the purchase and installation of equipment for experimental purposes;"

Cost of the work: Varied from \$10,000 per annum to nothing during years when project was inactive.

Results: When the Department's drainage investigations were initiated, most of the states had laws authorizing the establishment of drainage districts or public ditches on the initiative of the landowners, yet very little drainage had been accomplished under them except in the north central states. The laws of most states were not suited to the reclamation of large tracts which, without drainage, were unfit for cultivation. After a study of the laws under which effective drainage organizations had been established, new legislation was drafted for other states to provide a practical form of organization with power to levy and collect assessments for drainage and to issue bonds that would be a valid lien on the land. Assistance was given in formulating the North Carolina drainage district law of 1909, and since that time nearly all the states, including those in the irrigated region, have enacted new or amended laws along the general lines recommended by this Bureau. Problems involved in organizing, financing and administering drainage districts have been studied and a bulletin issued for the information and guidance of those responsible for the administration of drainage district affairs and in the organization of new projects. Special attention has been called to the necessity of giving careful consideration to the economic and agricultural problems involved in new enterprises with a view to discouraging the organization of unsound projects. A study has been made of drainage district assessments and the information published as a bulletin to assist district officials in equitably apportioning the cost, and preventing misunderstandings which are the principal cause of litigation.



Title of project: Customs, Regulations and Laws Relating to Drainage (continued)

Sub-project no. 3: Drainage District Organization, Administration and Development (continued)

Economic Importance: Organized drainage enterprises have been established in 35 states covering more than 84,400,000 acres, with an investment of \$680,732,000 and an annual maintenance and operating cost of more than \$7,600,000. A large part of this investment has been made by drainage districts organized and operating under state laws based upon the results of this project.

Estimated Annual Saving: Information is not available upon which to base a reliable estimate of the annual saving resulting from the work.

BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

Title of project: The control of soil erosion.
Date begun: 1915.
Date completed: In progress.

Authority: That part of the Appropriation Act, Bureau of Agricultural Engineering, as follows:
x x x x x; "for preparing plans for the removal of surplus water by drainage;" and that part of the Appropriation Act, Miscellaneous as follows: "To enable the Secretary of Agriculture to make investigations not otherwise provided for of the causes of soil erosion and the possibility of increasing the absorption of rainfall by the soil in the United States, and to devise means to be employed in the preservation of soil, the prevention or control of destructive erosion and the conservation of rainfall by terracing and other means."

Cost of work: Has varied widely, averaging about \$3,000 per annum from 1915 to 1928. Present annual expenditure approximately \$100,000 per annum.

Results: Soil erosion is caused chiefly by the rapid movement of run-off water down the slopes of the land surface that has been disturbed by man in cultivation, overgrazing with livestock, fires, etc. Thus the control of erosion is primarily a problem of hillside drainage or hydraulics - the construction of drainage channels or terraces on hillsides located in such manner that they will collect the run-off and conduct it from the hillside to a suitable outlet before it attains sufficient velocity to the soil. The object of this project is to develop suitable methods of erosion control, adapted to the various climatic, topographic and soil conditions existing in the United States, that will not interfere with the economic cultivation of the land. Under this project a field study was made in 1915 of methods of erosion control and three bulletins were issued, two on terracing practices and one on the reclamation and control of gullies. Since issued, these bulletins have been the basis for the work of the state agricultural extension agencies in terracing more than 15,000,000 acres of land and the reclamation of thousands of gullies. Since 1929 there has been established under this project in cooperation with the Bureau of Chemistry and Soils and interested state experiment stations, ten soil erosion experiment farms in ten of the eighteen principal regions where erosion is considered especially serious. These farms are located near Guthrie, Okla.; Temple Texas; Hays, Kansas; Tyler, Texas; Bethany, Missouri; Statesville, N. C.; Pullman, Wash.; Clarinda, Iowa; LaCrosse, Wisconsin; and Zanesville, Ohio. The work of this Bureau consists of investigating problems relating to the design and construction of satisfactory engineering control works such as terraces and soil-saving dams; the development of more efficient



Title of project: The control of soil erosion. (continued)

machinery for constructing terraces; and the requirements of farm machinery for operation over terraced land. The wide range of conditions existing on the various stations permits the development of the most efficient type of improvements and methods of construction for many varied conditions. The results secured to date warrant the confidence that has been placed in the practice of terracing as an effective method of erosion control. On a number of the stations we have found that on land in row crops terraces reduce erosion to but 2 to 3 per cent of what occurs on similar unterraced land. In cooperation with the Texas and Oklahoma Agricultural Experiment Stations we have found that in the semi-arid regions terraces conserve soil moisture and result in increased crop yields. Our work shows that terraces with variable grades are more efficient than those with uniform grades; that level terraces can be used in areas with sandy soils with permeable subsoils but are unsatisfactory in regions with heavy soils or impermeable subsoils. It has been found that the maximum grade for terraces should not exceed 4 inches per 100 feet instead of 6 inches in general use. Data relating to the most efficient type of terraces for each region is being furnished to the state agricultural extension services as rapidly as developed, for use in spreading the practice. A more efficient type of small terrace grader that materially reduces the cost of constructing terraces has been developed and is now being built by one of the machinery manufacturers. Methods of constructing terraces with large road grading equipment has been developed for regions where such equipment is available and the topographic conditions permit its use. This method of construction reduces the cost of terracing to from one-fourth to one-third the cost when using small equipment. Studies have been made of the operation of farm machinery over terraced land with a view to devising means of increasing the flexibility of such equipment. The maximum slope on which terraces are practical is being determined.

Economic importance: It is estimated that 75 per cent of the cultivated land in the United States is seriously affected by soil erosion and that over 20,000,000 acres of formerly cultivated land have already been destroyed. Much of the marginal and submarginal land now under cultivation has become such through excessive erosion and large additional areas, now being farmed, upon which good crops are being raised will have to be included in such areas unless steps are promptly taken to control erosion. On a large part of the land thus being eroded terracing is the most effective and practical method of control that has been developed. This is demonstrated by the fact that more than 15,000,000 acres have been thus protected during the past 15 years. A committee of landowners, loan company representatives and extension workers, representing three states, met in 1932 and decided that terracing resulted in an increase in

Title of project: The control of soil erosion. (Continued)

the value of the land protected of \$8.00 per acre. On this basis the work under this project has already resulted in an increase of more than \$120,000,000 in the value of agricultural lands during the past 15 years; and this amount will increase rapidly as the program of terracing grows. It is estimated that approximately 2,000,000 acres were terraced during the year 1932 and the practice is growing rapidly. Recent improvements in methods of constructing terraces, resulting from the work, has decreased the cost of terracing to the landowner as much as fifty cents to one dollar per acre, depending upon whether large or small equipment is used on the work.

Estimated annual saving: At present land is being terraced at the rate of 2,000,000 acres or more per year. The saving of at least fifty cents per acre in the cost of constructing terraces by methods developed under this project results in an annual saving of at least \$1,000,000 in the cost of such work. It is estimated that the terracing of 2,000,000 acres each year results in an increase of \$16,000,000 per year in the value of the land thus protected. Data is not available upon which to base the annual saving resulting from the protection of gullies by the construction of check dams and soil-saving dams but the amount is known to be large.

The agricultural experiment stations in the states in which our soil erosion experiment farms are located are all cooperating on this project. In addition, the Alabama State Experiment Station is conducting investigations relating to erosion on experimental plots equipped with an irrigation system that permits of the application of artificial rainfall.

BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

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Title of project: Examinations and surveys.
Date begun: 1905.
Date completed: 1919.

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows: "For investigating and reporting upon farm drainage and upon the drainage of swamp and other wet lands which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage; for the development of equipment for farm irrigation and drainage and for giving expert advice and assistance."

Cost of work: Varied widely; averaged approximately \$50,000 per annum.

Results: The first work in drainage investigations was an undertaking to assist groups of landowners who desired to reclaim lands that were swampy or subject to overflow, by advising with regard to the drainage works required and the cost of the improvements. To that end during the life of this project examinations and surveys were made for the reclamation or improvement of more than 11,000,000 acres. The reports for some of these projects outlined the general features of the works to be constructed, showing tentative locations and sizes and estimating costs from approximate data. In a great many instances, however, detailed plans and estimates were prepared from engineering surveys, many of which have been used by the districts' engineers in their reports to district authorities. In the making of the surveys, the districts cooperated by bearing a considerable part of the cost. The reports covering the design of drainage or flood protection improvements for thirteen representative districts have been printed by the Department.

In addition to the above, surveys and plans for tile drainage systems have been made on more than a thousand farms, following which the farm owners have constructed the recommended improvements as demonstrations for the various localities. On many of these farms instructions in the principles of farm drainage and in construction methods have been given to groups of farmers called together by extension agents of the State agricultural colleges. For this farm drainage work, engineers have been stationed, for various periods of time, in ten of the States, cooperating with the agricultural colleges. Gradually the colleges were able to take over this type of work and thus permit the Department to take up many sorely needed research problems relating to agricultural drainage.

Title of project: Examinations and surveys.

Economic Importance: The Bureau of the Census shows that since the starting of this project approximately 61,000,000 acres have been organized into drainage districts and drainage improvements constructed costing in excess of \$575,000,000. A very considerable part of this work was done in accordance with recommendations and plans made under this project. In addition, a large part of the farm drains constructed on more than 44,000,000 acres of cultivated land are the direct result of this work or of demonstrations installed under the direction of our engineers.

Estimated Annual Saving: It is impractical to make an estimate of the annual saving resulting from this work. Millions of acres have been furnished with improved drainage and the annual increase in income to landowners resulting from the work is undoubtedly large.

No similar project is being carried on by State experiment stations.

BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

Title of project: Flow through culverts.
Date begun: 1922.
Date completed: 1925.

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows: "For investigating and reporting upon farm drainage and upon the drainage of swamp and other wet lands which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage; for the development of equipment for farm irrigation and drainage and for giving expert advice and assistance; for field experiments and investigations and the purchase and installation of equipment for experimental purposes."

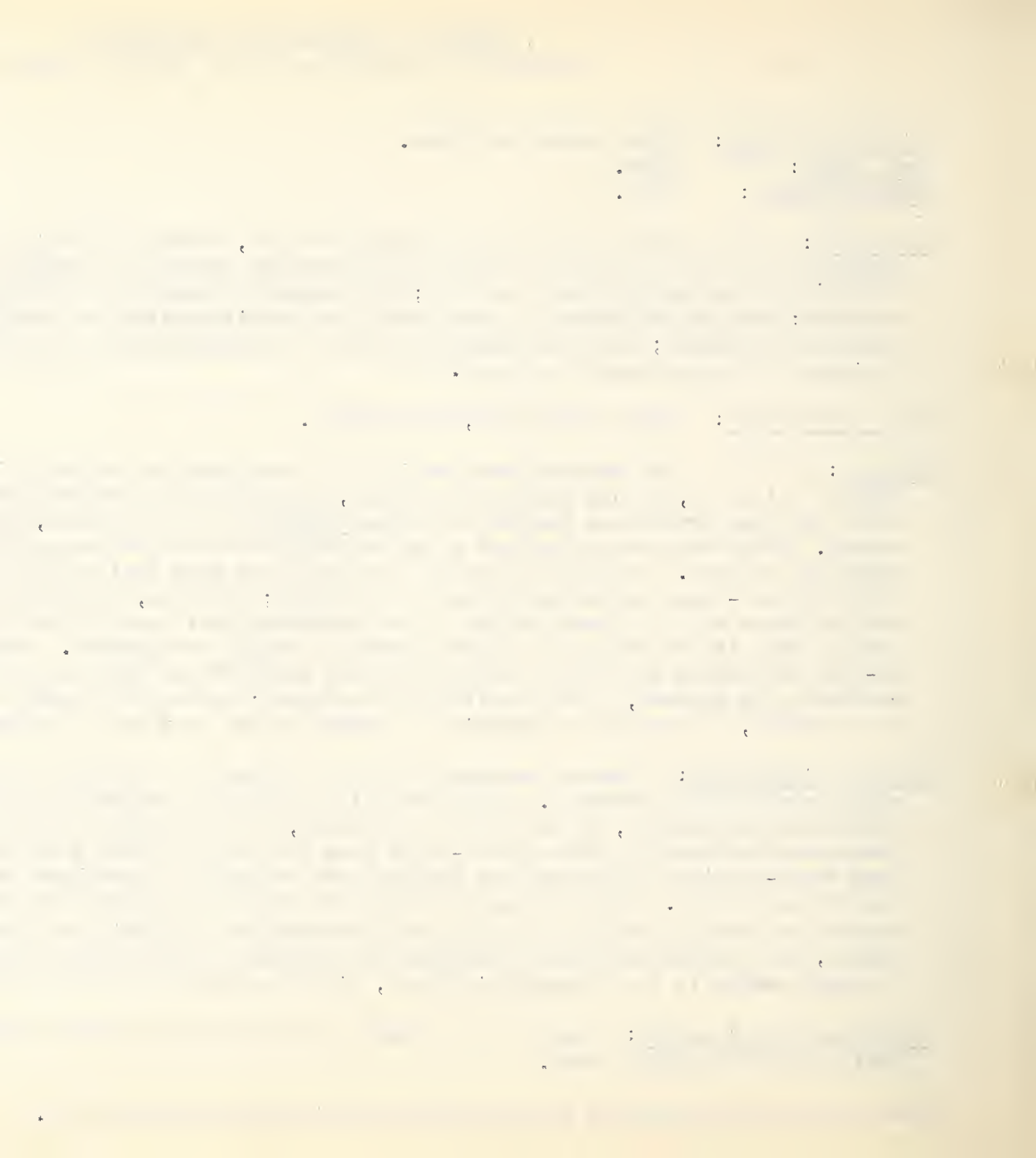
Cost of the work: Approximately \$7,500 annually.

Results: The general practice in the installation of culverts in highway and railroad work has been to calculate, by one formula or another, the quantity of water that the culvert would have to carry and then provide an opening of a size thought to be sufficient, allowing a liberal margin of safety. Little attention has been given to the relation of the design of the culvert itself to its carrying capacity. The results of the investigations show that by giving thought to details of construction - such as the smoothness of the walls; the size, shape and form of the culvert entrance; and the shape of the culvert outlet - the cross-sectional area of the culvert opening can be made smaller than is the case where these factors of design are ignored. For example, it was found that a 12-inch corrugated metal pipe culvert has only about 67 per cent of the carrying capacity of a 12-inch concrete pipe culvert, other conditions being equal; and that by merely changing the form of entrance to a culvert, an increase in capacity of almost 10 per cent can be secured.

Economic importance: There is scarcely a mile of highway or railroad in this country on which at least one culvert is not necessary. The same will be true with respect to future construction. The conscientious application, on the part of engineers, of the results of this work - these results having been made available by publication - will mean that at the small cost of taking pains, culverts of less cross-sectional area than now employed can be used to accomplish the same results, with a resulting saving in cost. This is true not only with regard to highway culvert construction but also in respect to certain structures used in the drainage and irrigation of agricultural land. Outlets through levees, and intakes and outlets employed in connection with drainage pumping plants such as are operated in large number in the Mississippi Valley, will also benefit from the results of these investigations.

Estimated annual saving: There are no actual data available on which could be computed the annual saving due to the above work.

This project was carried on in cooperation with the University of Iowa.



BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

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Title of project: Excavating Machinery Used in Land Drainage.
Date begun: 1913.
Date completed: 1917.

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows: "For investigating and reporting upon farm drainage and upon the drainage of swamp and other wet lands which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage; for the development of equipment for farm irrigation and drainage and for giving expert advice and assistance."

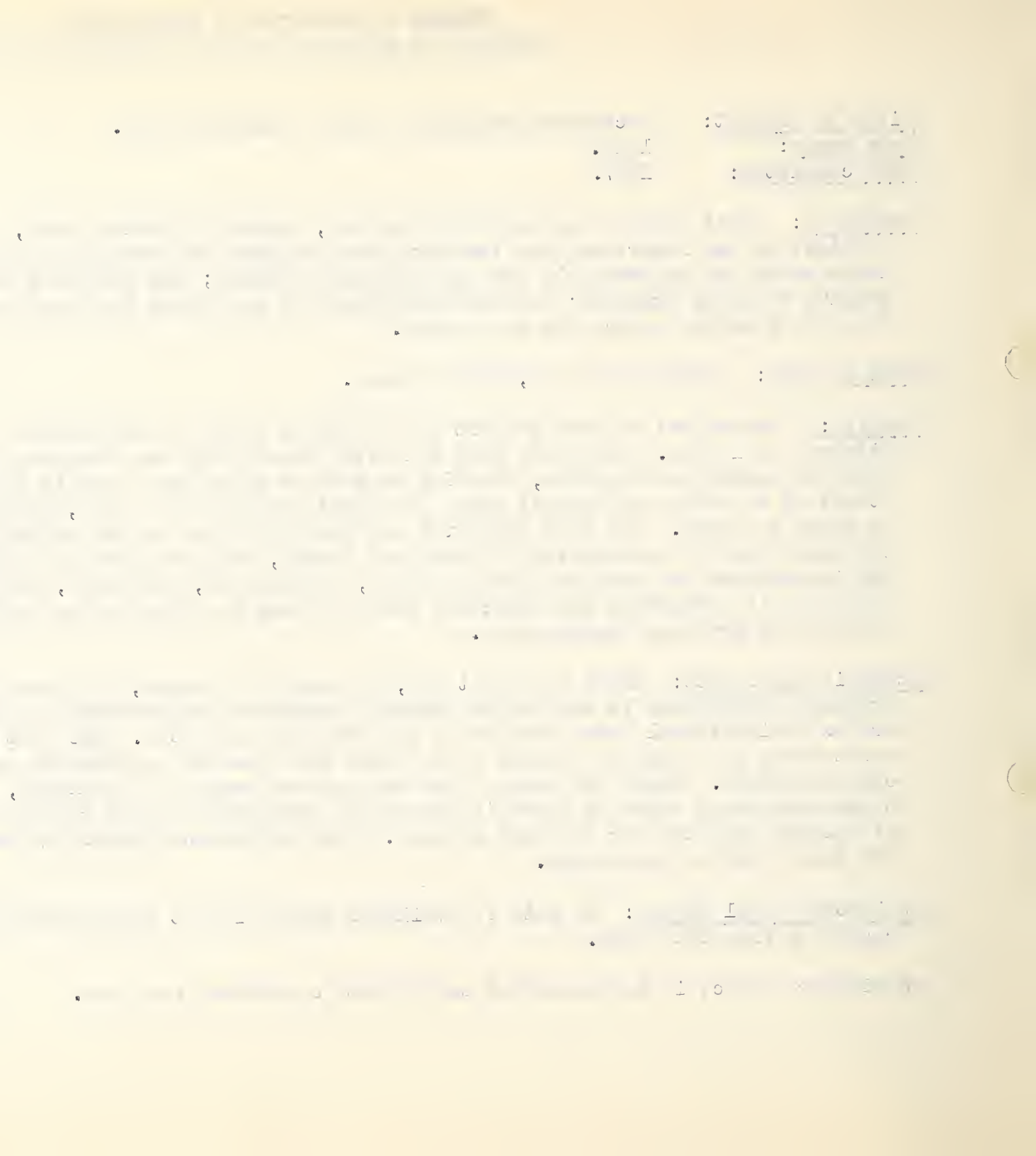
Cost of work: Approximately \$3,500 per annum.

Results: The object of this project was to make a study of methods and equipment used in constructing ditches and levees. Data have been collected concerning the character of work performed by various types of excavating machines, the kind of work to which each type is adapted and the cost of construction by different methods under different conditions of soil, water, timber growth, and size of ditch or levee. The data collected has been published as two bulletins, one on excavating equipment used in constructing ditches and levees, and the other on tile trenching machinery. The information has assisted manufacturers, contractors, engineers, and drainage district officials in perfecting and selecting machinery and in reducing the cost of constructing and maintaining drainage improvements.

Economic Importance: There are about 215,000 miles of ditches, tile drains and levees in organized drainage enterprises in the United States in addition to thousands of miles of ditches and tile drains on individual farms outside of the drainage districts. The cost of constructing and maintaining this immense mileage of drainage improvements is directly affected by the kind of equipment used. Where the proper type and size of machine is employed, the cost of constructing or maintaining a ditch or levee is materially reduced over that resulting when a type or size of machine unsuited for the work is used. This difference frequently amounts to several cents per cubic yard of excavation.

Estimated Annual Saving: No data is available upon which to base an estimate of the annual saving resulting from this work.

No similar project is being carried on by State experiment stations.



BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

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Title of project: Flow of water in drain tile.
Date begun: 1915
Date completed: 1919.

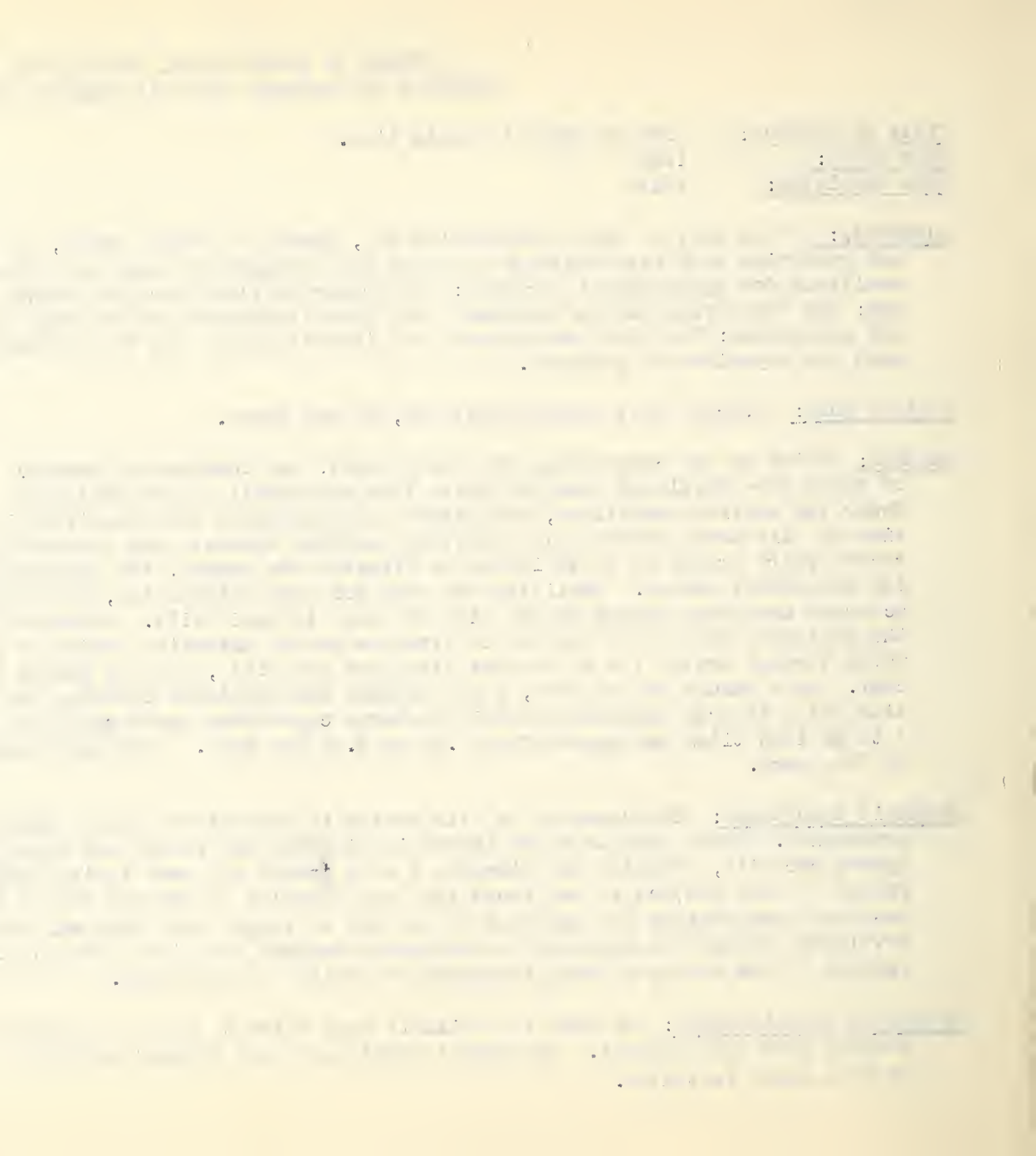
Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows: "For investigating and reporting upon farm drainage and upon the drainage of swamp and other wet lands which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage; for the development of equipment for farm irrigation and drainage and for giving expert advice and assistance; for field experiments and investigations and the purchase and installation of equipment for experimental purposes.

Cost of Work: Average cost approximately \$8,000 per annum.

Results: Prior to the undertaking of this project, the formulae in general use for computing the velocity of water were developed when all drain tile were small as compared with the larger sizes used today. Under the earlier conditions, when other considerations had relatively large weight in determining the size of tile used, accuracy in computing carrying capacity was comparatively unimportant; but in recent years drains 12 to 48 inches in diameter are common, and knowledge of the capacity is essential for economical design. Realizing the need for such information, this project was undertaken to obtain accurate knowledge regarding the flow of water in drain tile. Experimental equipment was set up at the Arlington Experiment Station in Virginia and an extensive series of measurements of the flow of water through drain tile of various sizes and materials, laid at grades ranging from 0.5 to 1.5 per cent. As a result of the work, a new formula was developed covering the flow of water through drain tile and a diagram prepared showing discharge capacities based upon this project, covering sizes from 4 to 48 inch tiles and grades from 0.04 to 3.00 per cent. A bulletin was issued covering the results of this work.

Economic Importance: The capacity of tile drains is a matter of great importance in designing such improvements. Where tile 24 to 48 inches in diameter and larger are installed at a cost of \$8,000 and upward per mile, reducing the diameter 2 or 3 inches may mean saving \$500 to \$1,500 per mile. As a result of this project it was found that the formulae in general use in computing sizes of tile drains were too conservative and resulted in the use of larger tile than was necessary. The new formula developed enables the engineer to accurately compute the size of drain tile required and its use results in the saving of many thousands of dollars on such work.

Estimated Annual Saving: No data is available upon which to base an estimate of the annual savings resulting from this project. The amount saved each year depends entirely upon the number of miles of tile drain installed.



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BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

Title of project: Reclamation of tidal marshes.
Date begun: 1906. (Not active in 1907 to 1909)
Date completed: 1911.

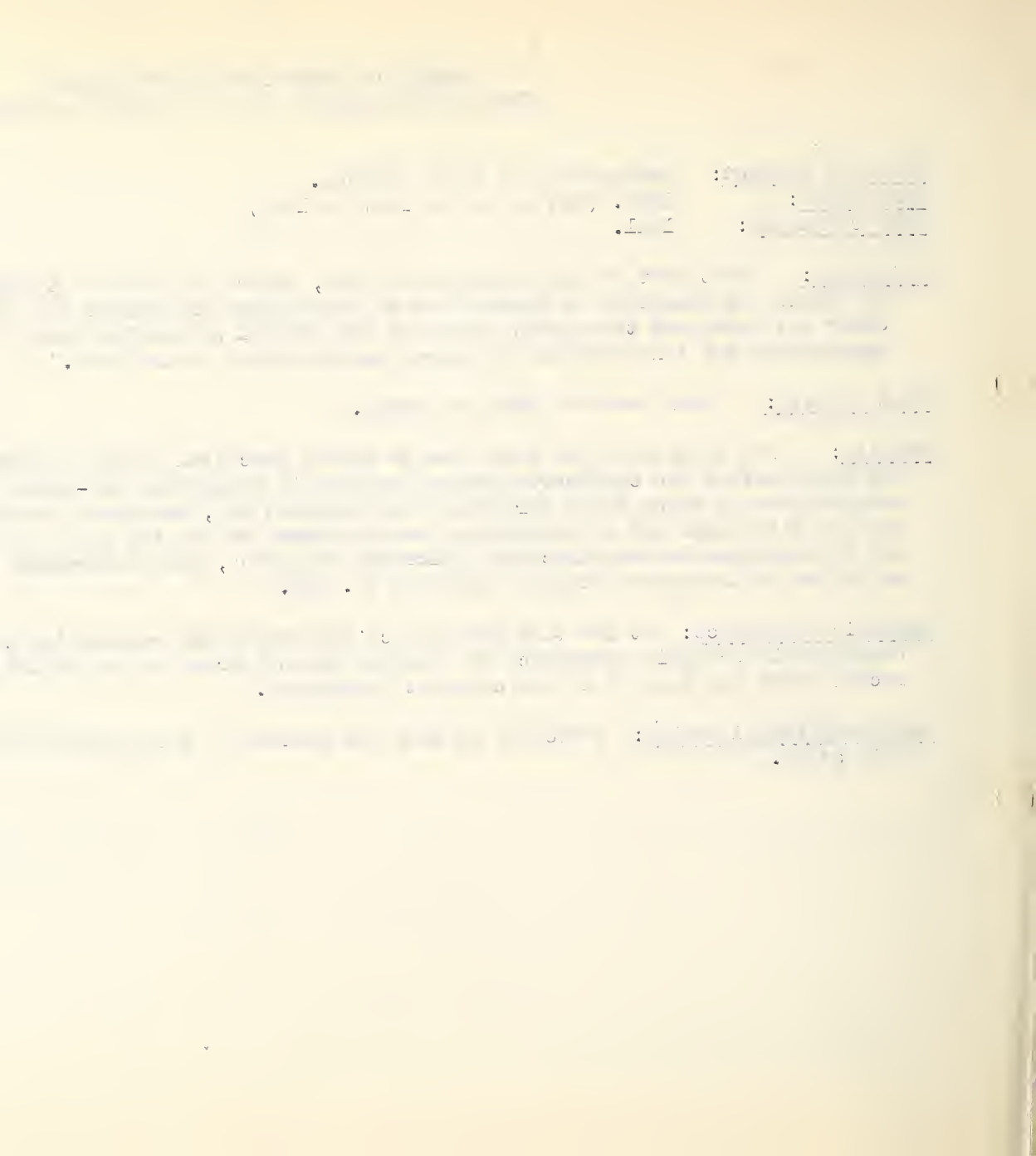
Authority: That part of the Appropriation Act, Office of Experiment Stations, as follows:
"To enable the Secretary of Agriculture to investigate and report upon the drainage of swamp and other wet lands and to prepare plans for the removal of surplus water by drainage and for the preparation and illustration of reports and bulletins on drainage."

Cost of work: Four years at \$800 per annum.

Results: The purpose of the study was to deduce practical rules of procedure for designing and constructing the engineering works required in reclaiming sea-coast marshes. From detailed examinations of diked areas northward from Delaware Bay, methods of constructing levees for various situations and of protecting them from wave action and other disintegrating influences, and of designing and constructing sluiceways and gates, were determined and the results published as Office of Experiment Stations Bulletin No. 340.

Economic importance: At the time the project was active the reclamation of tidal basins was of considerable economic importance to extended coastal areas in the United States but during recent years has been of little economic importance.

Estimated annual saving: There are no data for estimating the annual saving resulting from this study.



BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

Title of project: Design of drainage structures.
Date begun: 1922
Date completed: 1925.

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows: "For investigating and reporting upon farm drainage and upon the drainage of swamp and other wet lands which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage; for the development of equipment for farm irrigation and drainage and for giving expert advice and assistance; for field experiments and investigations and the purchase and installation of equipment for experimental purposes."

Cost of work: Approximately \$3,000 per annum.

Results: The object of this project was to develop effective and economical types of drainage structures such as gates, sluices, inlets, drops, and silt basins for open ditches and tile drains. Such structures were studied in the field from the standpoint of operation and construction and economical designs were developed for each type of structure. The results of the work were made available through publication as Department Bulletin No. 1408, "Structures Used in Draining Agricultural Lands."

Economic importance: In connection with the drainage of more than 100,000,000 acres of land, thousands of structures of the types covered by this project have been constructed, and additional structures will continue to be built as additional drainage work is done. The availability of designs of effective and economical plans in building new structures or renewing old ones will materially reduce the cost of the work to the landowner.

Estimated annual saving: No estimate can be made of the annual saving resulting from this work.

BUREAU OF AGRICULTURAL ENGINEERING.
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

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Title of project: Depth and spacing of tile drains.
Date begun: 1911.
Date completed: 1917.

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows: "For investigating and reporting upon farm drainage and upon the drainage of swamp and other wet lands which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage; for the development of equipment for farm irrigation and drainage and for giving expert advice and assistance; for field experiments and investigations and the purchase and installation of equipment for experimental purposes.

Cost of work: Approximately \$4,000 per annum.

Results: Investigations were conducted to determine the most satisfactory depth and spacing for tile drains in the Houston clay soils of Alabama and Mississippi and in the coastal plains region of North Carolina. Before the undertaking of this work, it was generally believed that the Houston clay soils of the "Black Belt" of Alabama and Mississippi could not be economically tile drained. It had been found that drains spaced 20 to 30 feet apart and 20 to 24 inches deep were unsatisfactory. As a result of this work it was found that drains spaced 75 to 80 feet apart and $3\frac{1}{2}$ to 4 feet deep resulted in good drainage, due to the increased depth of drains. In the coastal plains section of North Carolina, where the practice was to place drains 60 to 75 feet apart and 3 feet deep, it was found that drains spaced 100 to 125 feet apart and 4 feet deep resulted in good drainage.

Economic importance: There are millions of acres of cultivated land in the two regions covered by this report that require tile drainage to insure good crops. The results of this work permit a saving of \$15 to \$20 per acre or more in installing tile drainage systems in these areas.

Estimated annual saving: There is no data available upon which to base an estimate of the annual saving resulting from this project. Such saving depends entirely upon the amount of tile drainage done each year.

BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

Title of project: Irrigation in the Humid Region.
Date begun: 1909.
Date completed: 1930.

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows:
For the development of equipment for farm irrigation and drainage, and for giving advice and assistance; for field experiments and investigations and the purchase and installation of equipment for experimental purposes.

Sub-project no. 1: Operation and Design of Pumping Plants for Rice Irrigation.
Date begun: 1928
Date completed: 1930

Authority: (Ibid)

Cost of Work: Approximately \$2,500 per annum.

Results: The object of this project, which was carried on in cooperation with the Arkansas Agricultural Experiment Station at the Rice Experiment Farm, Stuttgart, Ark., was to determine the most economical methods and costs of pumping water from wells for rice irrigation; study the factors affecting overall efficiency of the pumping plants; and to determine the rate, time, amount and method of application of water and the effect on the crop. Prior to taking up of this project there was no reliable information relative to the development and use of ground-water for the irrigation of rice in Arkansas and in adjacent states. Past work has been done with little or no engineering design or supervision and as a result a large majority of the pumping plants were inefficient and expensive to operate, and could not supply the water required. As a result of this work, it was determined that in Arkansas and adjacent states a total depth of from 24 to 30 inches of water during the growing season will irrigate a rice crop. For early rice a depth of 24 to 27 inches is necessary, for a crop composed of both early and late varieties, usually about half of each, a total depth of 27 to 30 inches is required. These figures include the rainfall insofar as it supplies water which would otherwise have to be pumped. Where the land is somewhat level, the subsoil impervious, and the water used in an economical manner, it was found that a flow of water equal to 1 cubic foot per second or 450 gallons per minute was sufficient to irrigate 80 acres. Efficient types of pumping plants and methods of

Title of project: Irrigation in the Humid Region. (continued)

Sub-project no.1: Operation and Design of Pumping Plants for Rice Irrigation. (continued)

operation were determined. The results have been made available by publication by the Arkansas State Agricultural Experiment Station as Bulletin No. 261.

Economic Importance: In Arkansas alone there are approximately 1,000 farms on which more than 150,000 acres are irrigated by pumping plants with a total of more than 66,000 horsepower, costing more than \$6,800,000. The results obtained on this project indicate definitely the amount of water required for rice irrigation in that region; recommends methods of making more efficient use of present pumping equipment, and the types of equipment to install when existing plants are worn out. The results can be applied to regions in adjoining states where pumping from wells is practiced.

Estimated Annual Saving: It is estimated that the results of this investigation, properly applied, will reduce the cost of pumping for rice irrigation in the Arkansas field by at least \$2 per acre per year or a total of approximately \$300,000 per year. In addition, the more efficient application of water will materially increase the crop yield at no increase in the cost for labor or equipment.

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Sub-project no. 2: Irrigation in Florida
Date begun: 1909
Date completed: 1916

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows:
for the development of equipment for irrigation and drainage and for giving expert advice and assistance; for field experiments and the purchase and installation of equipment for experimental purposes.

Cost of Work: Varied widely; averaged about \$2,000 per annum.

Results: Methods of irrigation have been developed that are widely accepted by truck growers and orchardists in Florida and the South Atlantic States. Installation errors and losses due to poor operating management have been reduced; plants in operation have been studied and a constant improvement in the design of new plants has been secured. A low-pressure clay pipe line system of surface irrigation suitable for the region has been developed. The results have been made available in bulletin form.

Economic Importance: The wide acceptance of irrigation attests to the value of the practice in the estimation of truck growers and orchardists in the South Atlantic States. The low-pressure pipe system of surface distribution has been widely adopted in the citrus groves of Florida.

Estimated Annual Saving: No reliable data is available upon which to base an estimate of the annual saving resulting from this project. In dry years returns from irrigated lands are frequently double those from unirrigated lands. In periods of extreme drought irrigation may mean the difference between a good crop and a complete failure.

Sub-project no. 3: Surface Irrigation in the Eastern States.
Date begun: 1909 and continued intermittently.
Date Completed: 1928

Authority: (Ibid)

Cost of Work: Has varied widely. During last ten years averaged about \$300 per annum.

Results: In certain sections of the humid regions the rainfall is frequently so distributed through the year that crops often suffer from the lack of moisture during the growing season. The object of this project was to develop a method of irrigation adapted to conditions in the humid section that would be less expensive than the method of spray irrigation generally followed. Investigations and experiments have been conducted to determine the conditions under which surface irrigation can be used to advantage and methods and equipment have been developed, and a bulletin covering the work has been issued.

Economic Importance: There are large areas in the humid section where crop yields are frequently materially reduced by periods of drought during the growing season. In many areas, especially where high priced crops are grown, irrigation can be profitably practiced. There is no reliable data as to the extent of such areas but they are generally recognized as being large. It is estimated that on at least 50 per cent of the area to be benefitted by irrigation, the surface method can be practiced at an average saving of at least \$50 to \$100 per acre over methods generally used.

Estimated Annual Saving: There are no reliable data upon which to base an estimate of annual resulting from this work.

Sub-project no.4: Test of Spray Irrigation Equipment.

Date begun: 1928

Date completed: 1929

Authority: (Ibid)

Cost of Work: Approximately \$750 per annum.

Results: The object of this project was to determine the efficiency of different types of spray irrigation equipment in distributing water uniformly over the area irrigated. Tests were made of the operation of different types of nozzles and other distributing equipment. It was found that much more uniform and satisfactory irrigation resulted with some types of equipment than with others. A bulletin has been issued outlining the results obtained.

Economic Importance: Spray irrigation is extensively used in certain regions in New Jersey, Pennsylvania and Florida and the practice is spreading to other regions where high priced crops are grown. The results of this investigation make it possible for the landowner to determine the results that can be expected with different types of equipment and to avoid the purchase of inefficient and unsatisfactory types.

Estimated Annual Saving: Lack of data makes it impossible to estimate the annual saving resulting from this work.

BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

Title of project: Utilization of land in drainage enterprises.
Date begun: 1926
Date completed: 1928.

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows: "For investigating and reporting upon farm drainage and upon the drainage of swamp and other wet lands which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage; for the development of equipment for farm irrigation and drainage and for giving expert advice and assistance; for field experiments and investigations and the purchase and installation of equipment for experimental purposes."

Cost of work: \$2,800 per annum.

Results: The object of the investigation was to determine the extent to which the land included in organized drainage enterprises had been put to use, the conditions that operated to prevent or delay utilization of those lands, and the relation of incomplete utilization to the problems of financing drainage developments. Many settlers who had purchased land in the enterprises had been unable to complete payment for it; tax delinquencies were becoming serious; and some enterprises had defaulted in payment of their bonds. The study collected data with regard to 4,100,000 acres in 58 drainage enterprises considered representative of conditions in the drainage reclamation projects of the lower Mississippi Valley and the coastal plain of the south Atlantic states. About 16 per cent of the land had been improved before the drainage enterprises were organized and after an average of 12 years the improved portion had been increased to about 28 per cent; about one-fourth of the unimproved land had been brought into use in that time. In some enterprises no advance had been made. Location with regard to origin of settlers and community developments, fertility of soil, type of agriculture, land-sales policies and price of land were disclosed as the principal factors in comparing rates of development in different localities. High cost of drainage, in some districts average \$3.50 per acre, and of roads and schools were found to have greatly influenced tax delinquencies and the financial status of the enterprises. The results of the study have been published by the Department in Technical Bulletin No. 194.



Title of project: Utilization of land in drainage enterprises. (continued)

Economic importance: In the United States there are, according to the census of 1930, more than 84,000,000 acres in organized drainage enterprises, of which more than 20,000,000 acres are unimproved. The facts should be valuable in preventing inauguration of unwise undertakings.

Estimated annual saving: There are no data for estimating the saving to promoters, prospective settlers, and owners of the land proposed to be included in contemplated reclamations.



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BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF DRAINAGE AND SOIL EROSION CONTROL

Title of project: Pumping plants for Gulf Coast marsh lands.
Date begun: 1906.
Date completed: Work intermittent. Project closed 1922.

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows: "For investigating and reporting upon farm drainage and upon the drainage of swamp and other wet lands which may be available for agricultural purposes; for preparing plans for the removal of surplus water by drainage; for the development of equipment for farm irrigation and drainage and for giving expert advice and assistance; for field experiments and investigations and the purchase and installation of equipment for experimental purposes."

Cost of work: Varied widely; averaged about \$3,500 per annum when active.

Results: Methods of draining peat and marsh lands were developed; tests were made of low lift drainage pumping plants and recommendations were made for improving the design of equipment and efficiency of operation. Measurements were made of the subsidence of peat and muck soils after drainage to determine the effect upon pumping operations. In many places it was found that as much as 3 feet subsidence occurred in the first 3 or 4 years after drainage. This subsidence materially affects the design of ditches and of pumping plants. Methods of constructing levees on peat and muck soils were developed. The results obtained were published in several bulletins of the Department covering different phases of the work.

Economic importance: During the period covered by this investigation many drainage enterprises were being organized in the marsh lands of southern Louisiana and Florida. It was important to have accurate information as to the engineering and economic problems involved in reclaiming such lands in order to avoid unwise undertakings. The information obtained shows the difficulties that are encountered in reclamation projects in that region and the cost of development.

Estimated annual saving: There is no way of estimating the annual saving resulting from this work.

Title of project: Factors influencing the design, construction and maintenance of large tile drains.
Economical use of large tile for land drainage.

Date begun: 1925

Date completed: 1926

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows: "for investigating and reporting upon farm drainage ***."

Cost of work: Approximately \$2,500 per annum.

Results: The purpose of this project was to ascertain what conditions tend to increase or decrease the ultimate cost of drainage when large tile are used, and to work out the general conditions that determine when large tile are more economical than open ditches for land drainage. Tile of $3\frac{1}{2}$ to $4\frac{1}{2}$ feet in diameter had been installed many times in the upper Mississippi Valley where it appeared that open drains would have been more economical. The investigation involved study of construction and maintenance costs both for large tile drains and for open ditches. Data on maintenance and repair costs were not previously available. Comparison was made of costs in 106 drainage districts in Minnesota, Iowa, Wisconsin and Illinois. At material and labor prices prevailing in that region in 1922 to 1925, maintenance costs for tile drains averaged approximately two-thirds of 1 per cent of the cost of the tile and labor of installation and for open ditch drains about 5 per cent of the cost of excavation and damages. Combining maintenance expenditures capitalized at $6\frac{3}{4}$ per cent per year, with installation costs, it was found that drainage with tile is about equal in cost to open ditches when purchase of tile and trenching, laying and backfilling is 70 to 100 per cent greater than the cost of excavation and damages for the open ditch. Large tile becomes relatively more economical as the depth of the drain increases. The effects of variations in prices upon relative costs of the two types of drains, and a method of estimating the actual amount of damages caused by an open ditch across farm land, were established by the Department in Technical Bulletin No. 269.

Economic importance: Public drains of tile exceeded 5,500 miles in 1930, according to Census statistics, and public open ditch drains 138,000 miles. The cost of the tile drains greatly exceeded \$70,000,000 and probably approached \$100,000,000. It is very important, especially under economic conditions existing during the past several years, that drainage as well as other improvements to be paid for by farm owners be designed economically.

Estimated annual saving: The saving resulting from this project could be estimated only upon information as to the districts that contemplated one kind of drains and used the facts published to determine

Title of project: Factors influencing the design, construction and maintenance of large tile drains.
Economical use of large tile for land drainage.

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Estimated annual saving: (cont'd) that the other kind would be cheaper in the long run. It is known, however, that less of the large size tile and a greater proportion of open ditches have been used in the past several years.

No similar project is being carried out by State experiment stations.

Title of project: Investigations of Farm Land Development.
Date begun: 1927.
Date completed: In progress.

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering "for investigations, experiments, and demonstrations*** and upon the engineering problems involved in adapting physical characteristics of farm land to the use of modern farm machinery."

Cost of work: Has varied - 1933, \$14,650.

Results: The purpose of this investigation is to determine the engineering adjustments which are needed upon typical farms and the benefits which will accrue from the adoption of improved methods or equipment by the land owners. Seventy-five farms in various sections of the country of different kinds, various sizes, and with wide variation in soils, topography and climate have been surveyed. These farms cover a wide variety of conditions but in almost every case it was found that the fields were too small and irregular in shape for profitable cultivation, that generally more power than is needed is available on these typical farms, and that the farm business and equipment is not properly balanced. In cooperation with State agricultural colleges of the various States, detailed and coordinated plans for the development of each of these farms have been prepared. In each plan the farm business is treated as a unit so that the crops, livestock, buildings, field arrangement, power, and machinery are all in proper proportion to each other and to the farm business as a whole. On each of these farms it has been possible to project a plan which appears to be much more profitable than the one now being followed. Due to the low prices for agricultural products, very few farmers have been able to complete their development program but all of them are making such progress as their finances permit. If the suggested changes are made, the benefits resulting therefrom will be determined from the farmers' financial records.

Economic Importance: It is believed that the results of this investigation will be applicable to most of the farms in the United States, and certainly to those in sections where a variety of crops may be grown.

Estimated Annual Savings: No data is available on which to base an estimate of the annual savings.

No similar project is being carried out by State experiment stations.

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BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF STRUCTURES

Title of project: Livestock shelters and appurtenances.
Date begun: 1921.
Date completed: In progress.

Authority: Appropriation, Bureau of Public Roads 1921 to 1931.
Appropriation, Bureau of Agricultural Engineering, 1932 and 1933, an item under agricultural engineering, "*** For investigation, experiments, and demonstrations *** upon the design and construction of farm buildings and their appurtenances."

Sub-project no. 1. Relation of stable air conditions to milk production.
Date begun: 1930.
Date completed: In progress.

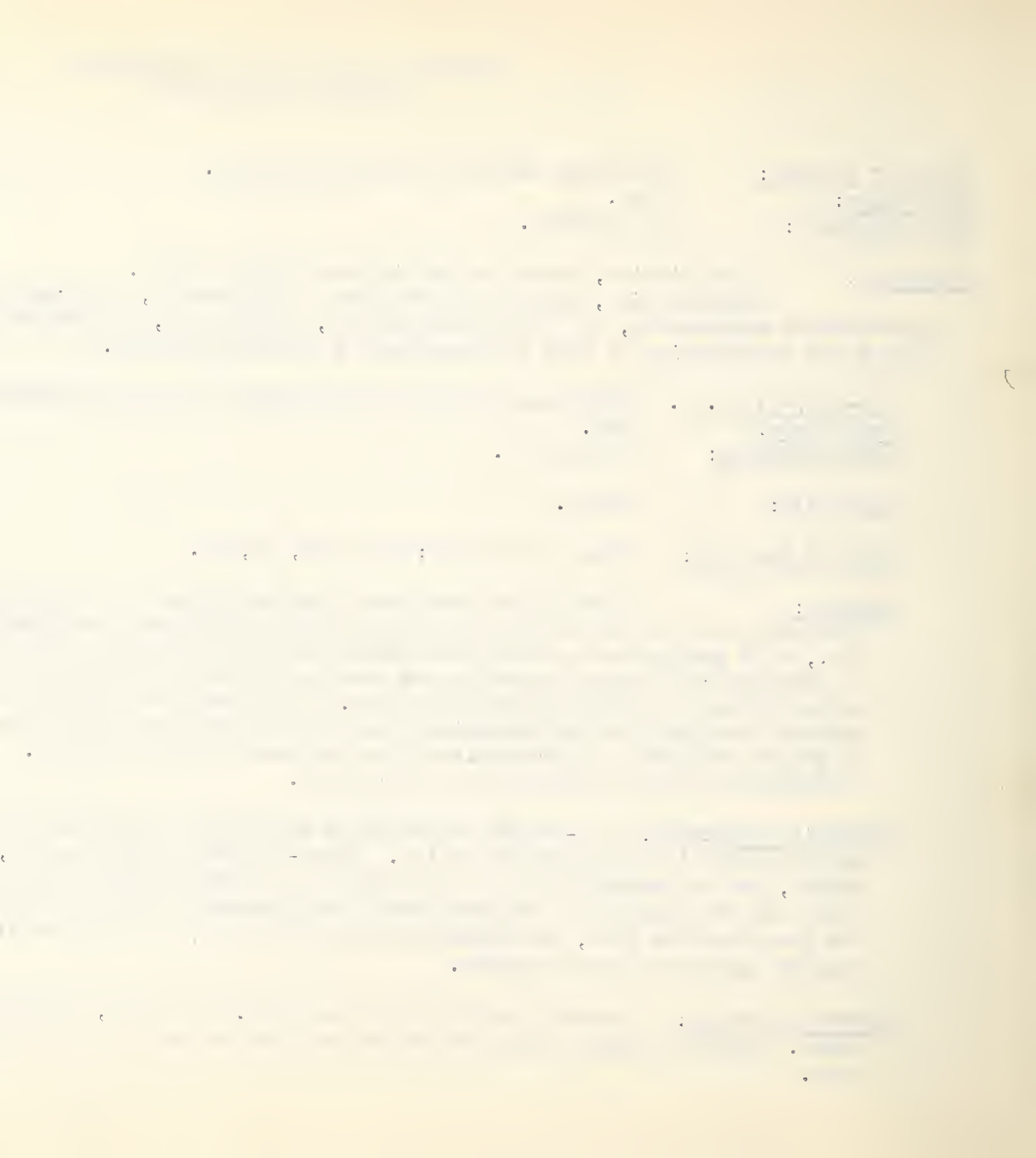
Authority: (Ibid).

Cost of the work: Costs have varied; for 1933, \$8,400.

Results: It was found that under the conditions in southeast Wisconsin, where the experiments were carried on in cooperation with the University of Wisconsin and Brookhill Farm, Inc., milk production was best with stable temperatures between 50° and 55° F. Sudden changes in temperatures reduced production as much as 15 per cent while drafts in some stables caused several cases of pneumonia among the cows. Such data are valuable in determining suitable types of construction and economical use of insulation for dairy barns and in planning stables to secure satisfactory circulation of air without injurious drafts. The report of the investigation is being prepared for publication.

Economic importance: Two-thirds of the dairy cattle of the United States are located in sections where housing is an important problem. Three-fourths of this number, or half of all dairy cattle, are in regions where it is necessary to stable milking cows 220 days per year or more. Hence the maintenance of desirable stable conditions is of great importance in maintaining the health of the cows, the production and the quality of the products, all of which has a decided bearing on public health.

Estimated saving: A possible saving of at least \$1.00 per cow, annually, is reasonably within reach. Hence an annual saving of several million dollars can be obtained as a result of this work.



Title of project: Livestock shelters and appurtenances (Cont).

Sub-project no. 2: Dairy barn ventilation.

Date begun: 1921.

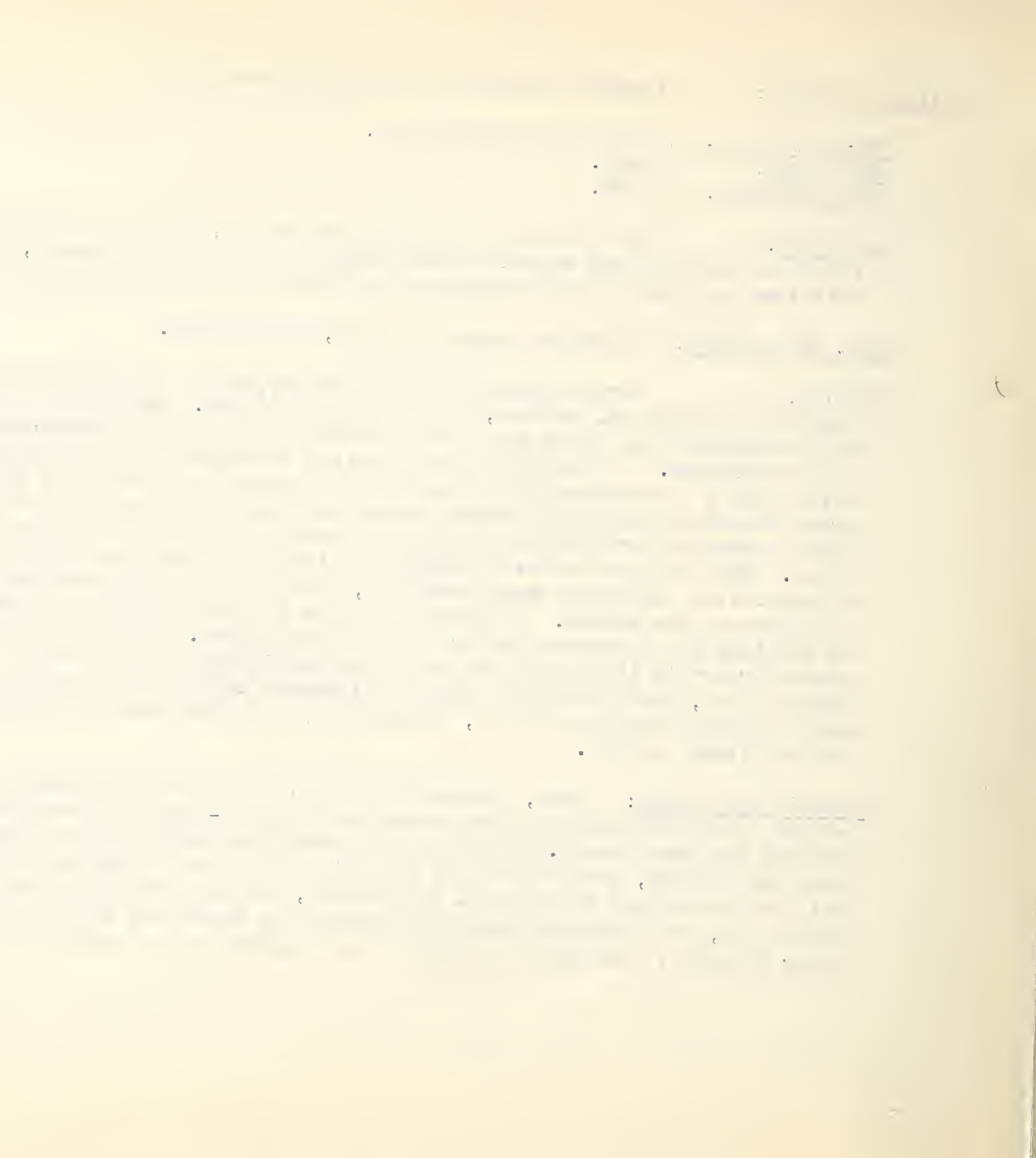
Date completed: 1930.

Authority: That part of the Appropriation Act, Bureau of Public Roads, as follows "*** for investigating farm domestic water supply and drainage disposal, the construction of farm buildings and other rural engineering problems involving mechanical principles***."

Cost of the work: Estimated average cost \$2,000 per year.

Results: Certain general principles governing the ventilating of stock shelters without the aid of mechanical devices, have been established. The range of winter temperatures that may be expected and which should be provided for in the construction of such buildings have been determined. It has been found possible to maintain a comfortable temperature in dairy barns with a circulation of air sufficient to admit of control of stable humidity, a factor of great importance affecting animal health and the durability of structural materials. There are many factors of definite or variable character affecting the design of ventilating systems for barns. Many facts of value to owners who install or operate ventilating systems and to designers of ventilating equipment were developed, and have been much used in improving the ventilating equipment on the market. A valuable feature of the findings are the indications of a number of problems of fundamental nature still to be solved. Farmers' Bulletin 1393, designed to guide farmers in installing and operating ventilating systems was published in 1924. Technical Bulletin 187, containing data which will enable engineers to design ventilating systems to meet specific local conditions, economically and with greater assurance of definite results was published in 1930.

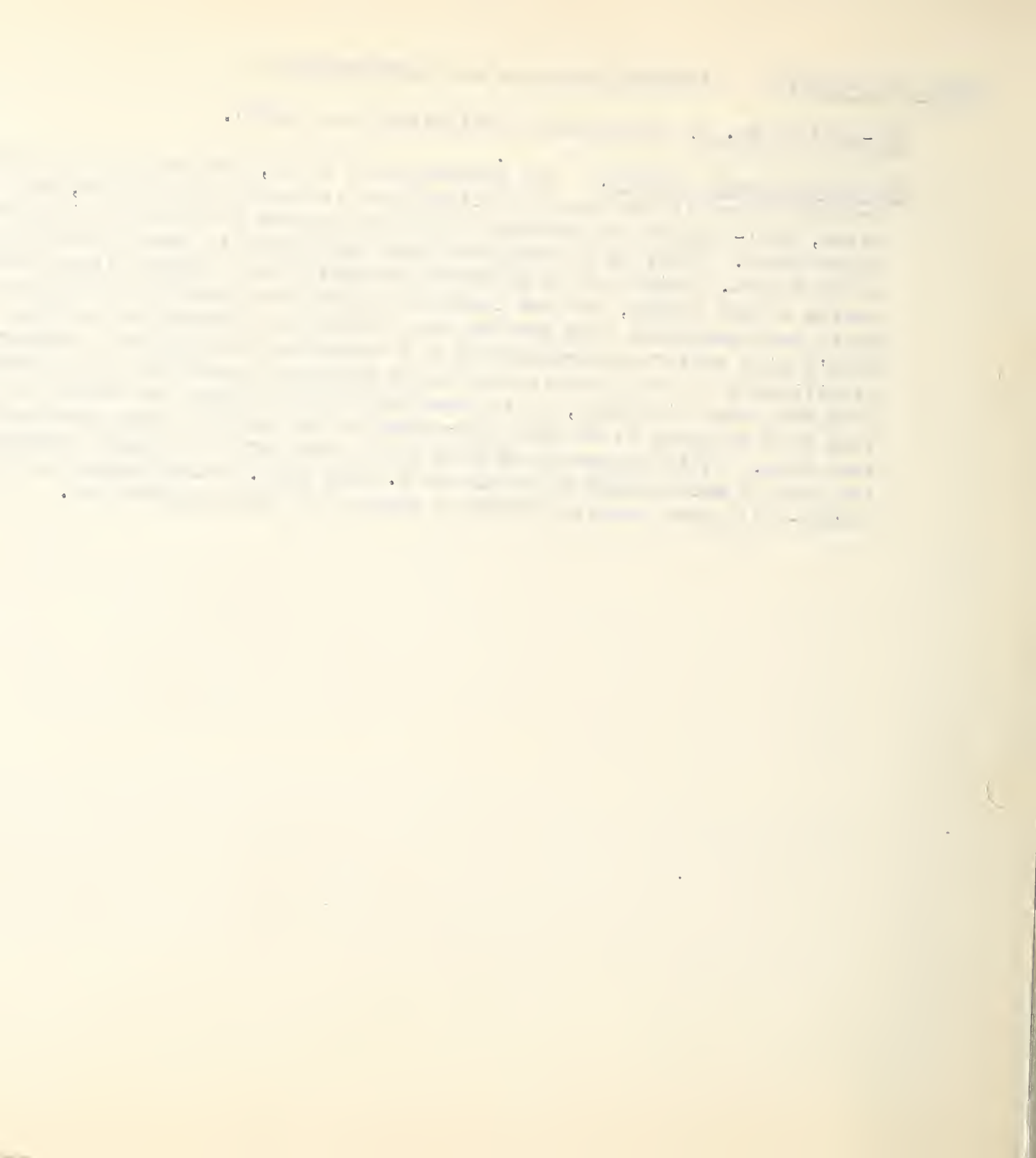
Economic importance: Clean, wholesome milk can be had only from healthy cows. In order to increase production breeders have developed the high-producing cow and a greater winter production of milk has been sought. Large winter production requires that tightly built shelter for the cows be provided, particularly in the colder sections of the country. Tightly constructed barns will be damp unless ventilation is provided, and the stabling of animals in dark, poorly-ventilated, damp barns affects their health and decreases their resistance to tuberculosis and other diseases. The same principles are involved in the ventilation of barns for other stock.



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Title of project: Livestock shelters and appurtenances.

Sub-project no. 2: Dairy barn ventilation (continued).

Estimated annual savings: The importance of clean, safe milk for children and invalids who are dependent upon it for their principal food is readily recognized, but the significance of a clean, well-lighted and properly ventilated stable as an aid to its production is not always appreciated. There is no data available upon which to base an estimate of the monetary value of this work. This must be measured indirectly by a longer life of the structure, better health of the animal, and the indirect influence of comfortable quarters on milk production. Tests have been made that show on the average an increase or decrease of 0.1 per cent in the herd's milk test for approximately a 4° decrease or increase in temperature. The practical significance of this fact is that under the usual conditions of intensive feeding of dairy cows and other livestock, it is more profitable to keep the animal at a comfortable temperature than to force it to burn extra feed or to draw upon body reserves of energy in order to keep warm. It is important to know that a fall of 1° in temperature below the critical increases the cost of maintenance of cattle by 1.4 per cent. An efficient ventilation system in a warmly-built barn permits effective control of barn temperatures.



Title of project: Livestock shelters and appurtenances.

Sub-project no. 3: Livestock buildings and equipment.

Date begun: 1922.

Date completed: 1929.

Authority: (Ibid).

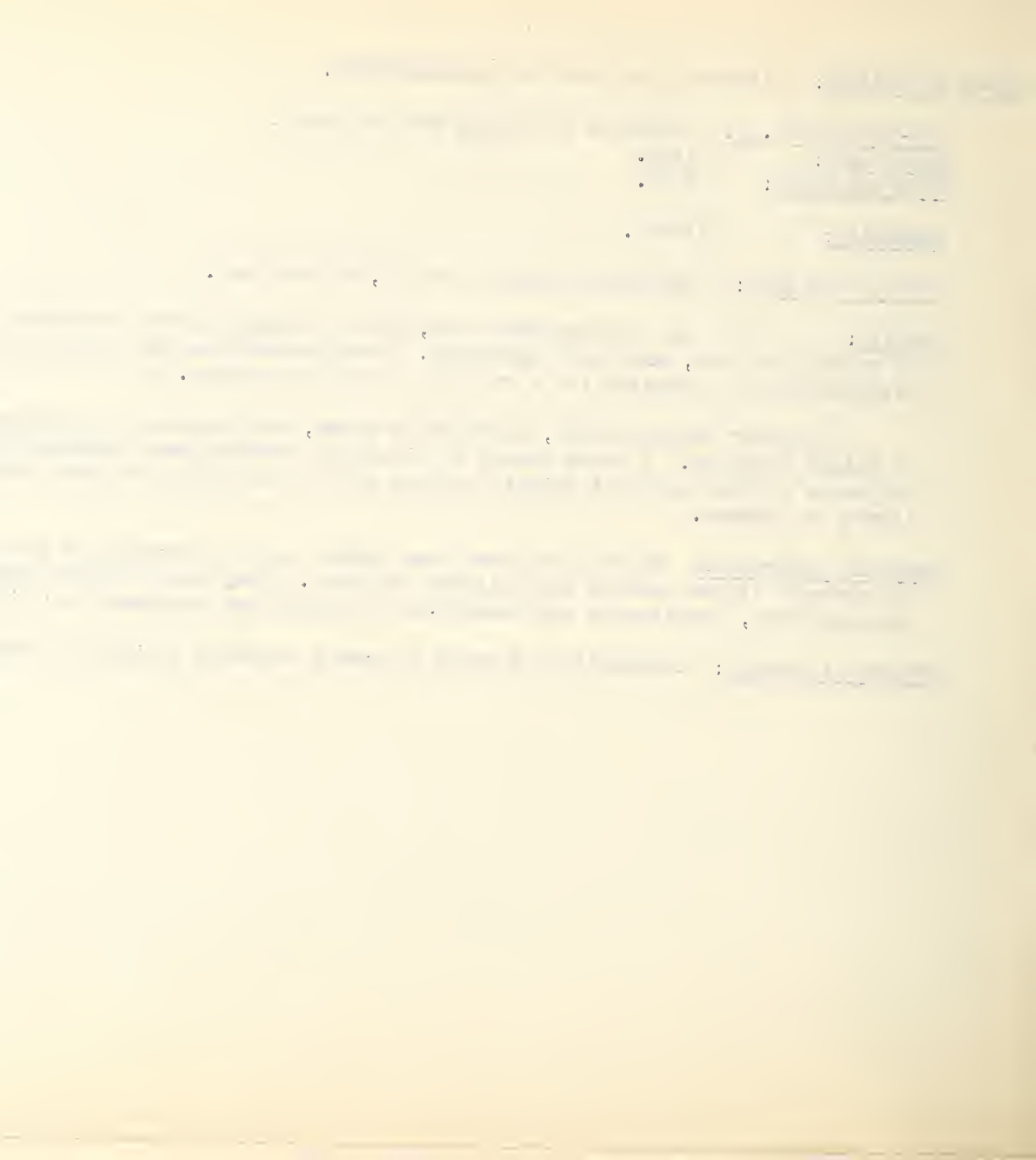
Cost of the work: Estimated average cost \$1,000 per year.

Results: By this research work, basic information was developed as to requirements of animal shelters, and their equipment. This information was used in the preparation of a large number of standards for a variety of farm structures.

Farmers' Bulletin 1350, Beef Cattle Barns, was prepared in cooperation with the Bureau of Animal Industry. A large number of plans and drawings were prepared to illustrate other bulletins of the Bureau of Animal Industry and of the Bureau of Dairy Industry, and for issue direct to farmers.

Economic importance: These plans have been widely used by farmers and extension workers and by students in the various agricultural colleges. They have promoted the construction of more sanitary, serviceable and economical buildings and equipment for livestock.

Estimated savings: Information on which to base a reliable estimate of savings is not available.



BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF STRUCTURES

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Title of project: Improvement of farm buildings.
Date begun: 1924.
Date completed: In progress.

Authority: Appropriation for Bureau of Agricultural Engineering for 1933, under an item "For investigations, experiments, and demonstrations xxx upon the design and construction of farm buildings and their appurtenances".

Sub-project no.1: Improvement of the farmhouse.
Date begun: Fiscal year 1932.
Date completed: In progress.

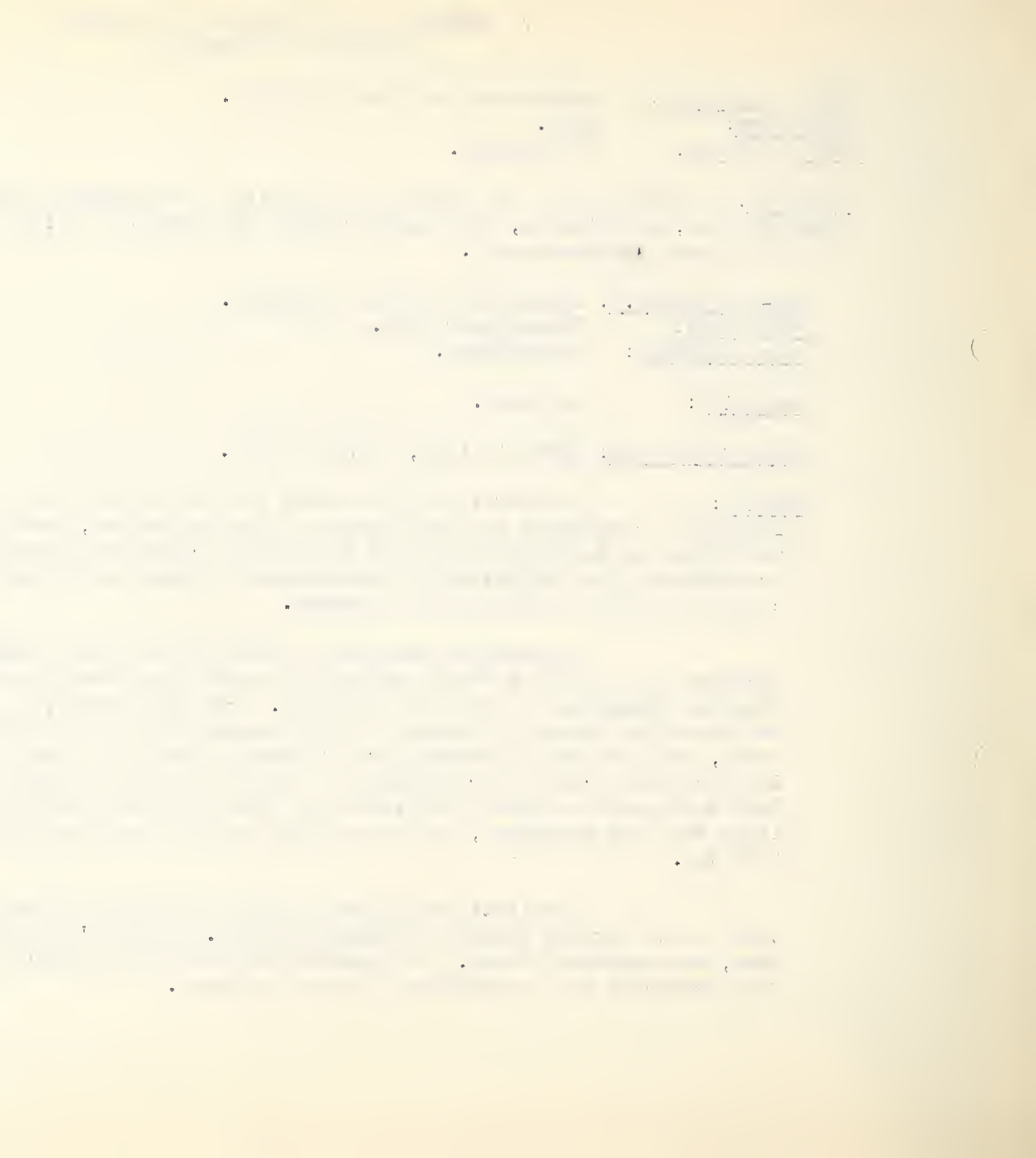
Authority: As above.

Cost of the work: \$4200 in 1932, \$2850 in 1933.

Results: A careful study was made in 1931 of available material concerning farmhouses. The Bureau cooperated with the Bureau of Home Economics, representatives of State colleges, and others in outlining desirable space and service requirements for farmhouses, and in the preparation of a collection of representative plans for farmhouses of which several thousand copies have been distributed to farmers.

Information obtained in field surveys made several years ago in different sections of the United States and that secured from other sources was supplemented by a field study of farmhouses in Ohio and Michigan. The investigations show clearly that farmhouses are generally lacking in convenient arrangement and modern facilities, as compared to city homes, and that few farmhouses are planned to meet farm needs to best advantage. Many existing farmhouses might be rearranged to provide better facilities at comparatively small expense. Considerable help toward improvement in rural housing is offered by state agricultural colleges and farm magazines, but the problem has not yet been attacked in a thorough and effective way.

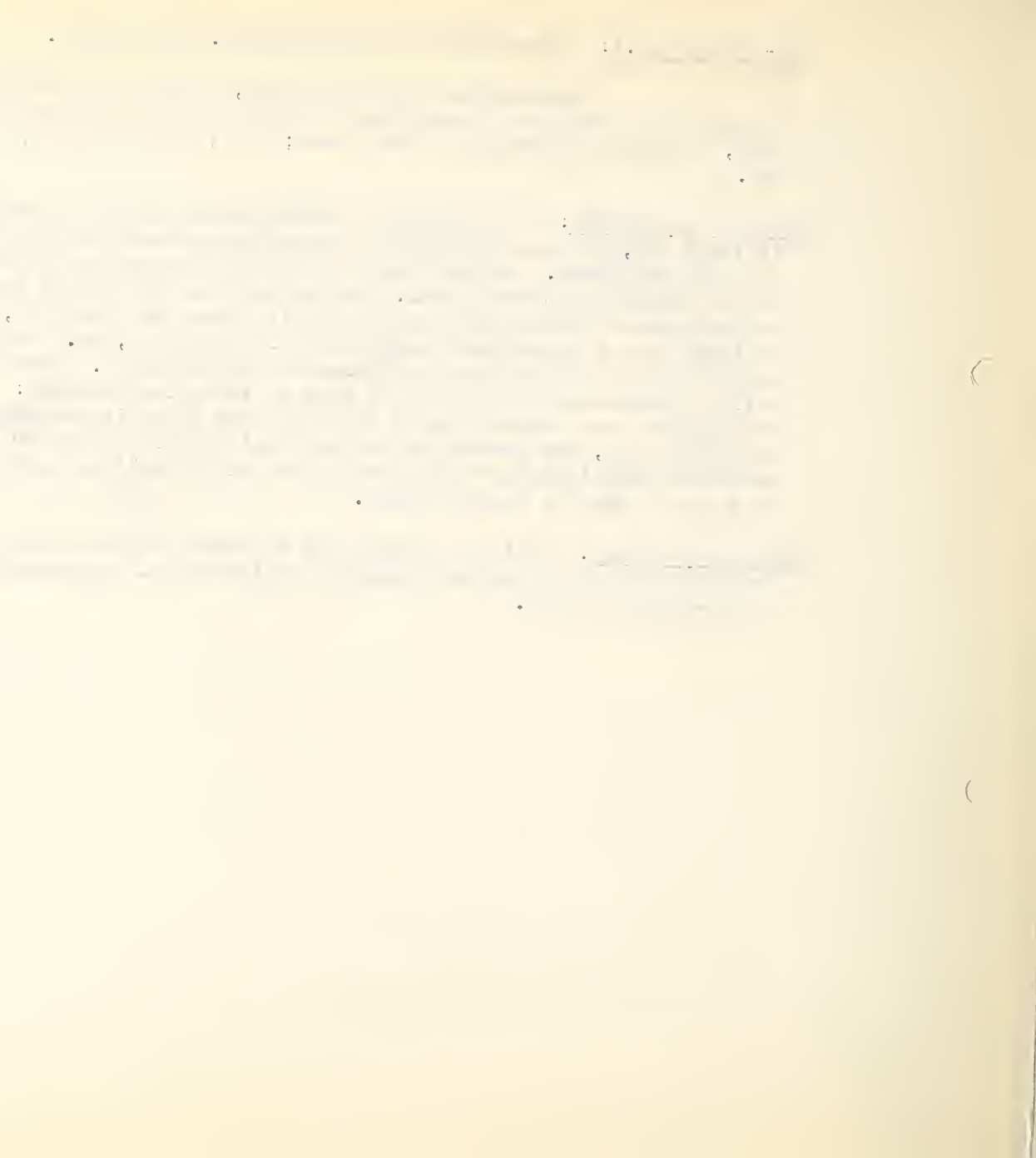
A bulletin on planning and remodeling northern farmhouses is now in preparation to aid farmers in their housing problems. Farmers' Bulletin 1698, Heating the Farm Home, was recently issued. It presents information on selection of heating equipment suitable for farmhouses and on methods of conserving heat.



Information on water supply, plumbing and sewage disposal for farmhouses was brought up to date, by preparation of material for use in revision of Farmers' Bulletins 1227, Sewage and Sewerage of Farm Homes; 1426, Farm Plumbing; and 1448, Farmstead Water Supply.

Economic importance: The building of farmhouses is going on continually. It is estimated that at least 100,000 farmhouses per year are needed to replace losses by fire or obsolescence and to equip new farms. In addition a great many farmhouses are remodeled or equipped with modern conveniences every year. During the ten year period 1920 to 1930 the gain in number of farmhouses equipped with modern lighting was more than 388,000, and the gain in number equipped with a piped water supply was more than 350,000. In most cases such installations are accompanied by changes in arrangement of the house. There are still more than five million farmhouses without one or both of these conveniences: Requests for farmhouse plans and reports from various states indicate that there is now much interest in new building and remodeling, due perhaps to the low cost of building under present conditions. It is therefore very important that plans which will result in satisfactory houses should be available to and used by farm builders.

Estimated savings: Savings through good planning reduce cost of construction somewhat, but the greatest gain is in the increased satisfaction, serviceability, and cause for pride in a well-planned house.



Title of project: Improvement of Farm Buildings.

Sub-project no.2: Use of steam for soil sterilization.

Date begun: 1932.

Date completed: Field work completed in 1932. Manuscript in progress.

Authority: As above.

Cost of work: \$1800 for 1932; \$3800 for 1933.

Results: Project not yet complete but preliminary analysis of data indicates that a substantial improvement in the technique of soil sterilization can be effected by application of information secured in this study.

Economic importance: Soil in commercial greenhouses at present is sterilized, generally once a year, by means of steam. According to conservative estimates of labor and fuel requirements, the cost of sterilization averages about \$450 per acre. In addition to the greenhouse acreage, there is a large acreage planted to tobacco seed and which has to be similarly treated.

Estimated annual saving: An estimate is not yet possible since the work has not been completed.

Title of project: Improvement of Farm Buildings.

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Sub-project no. 3: Study of modern vaporizing oil burners.

Date begun: 1933.

Date completed: In progress.

Authority: Appropriation, Bureau of Agricultural Engineering.

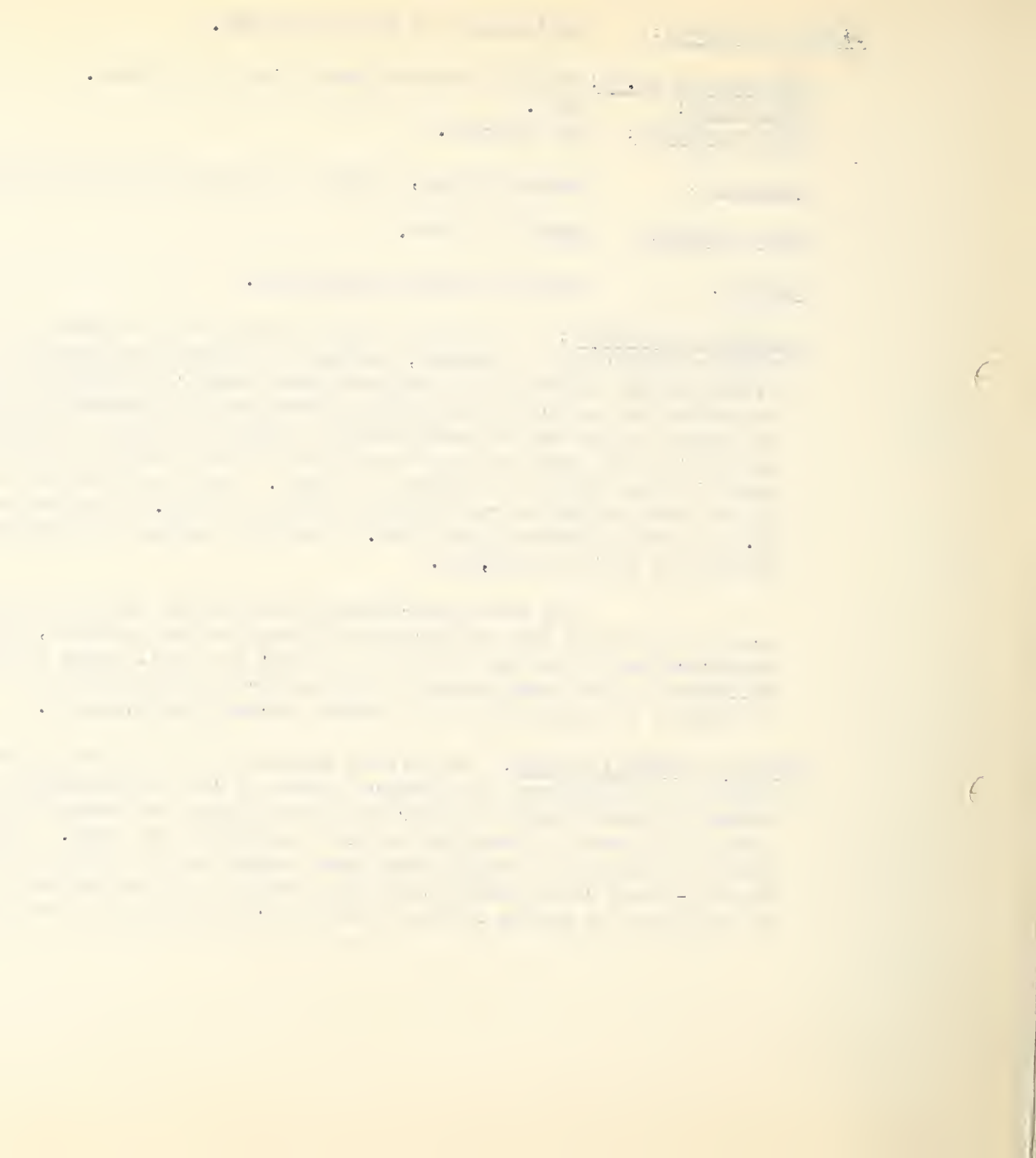
Cost of Work: \$2000 for 1933.

Results: Project recently commenced.

Economic importance: The type of oil burner being studied is a recent development and is readily applicable to cooking, heating of houses and heating of water in rural sections. It is especially suitable for sections where electric current is not available and for homes which have no central type heating system and is apparently the only practicable type of oil heater which may be substituted for coal or wood in the kitchen range. Since more than one-half of the homes of the country do not have central heating systems the potential interest in this type of equipment is large. The manufacturers of this new type of vaporizing burner have enjoyed a rapidly increasing business. The production for 1931 represented a 65.8 per cent increase over 1930. The total number of burners of the vaporizing type installed in 1931 was 148,212.

The work undertaken by the Bureau on the vaporizing burner will no doubt prove of value to the manufacturer as well as the consumer, since correspondence with manufacturers has indicated that the products are still being improved and experience with development of the older types of oil burners indicates that the findings of the Bureau will be used by the manufacturer in making further improvements.

Estimated annual saving: The direct dollars and cents saving can not readily be determined. There is an important sociological phase of the investigation in that the use of the oil burner promotes greater comfort and convenience and improved health and is well within the economical reach of many who are now using coal and wood. The oil fired kitchen range can be readily lighted and extinguished thus adding to the comfort of the home in the summer months. The oil-fired range lends itself well to the application of insulation to the oven in order to minimize the escape of heat into the rooms during the warm months.



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Title of project: Improvement of Farm Buildings.

Sub-project: no.4: Application of unit heaters to greenhouses

Date begun: 1933.

Date completed: In progress.

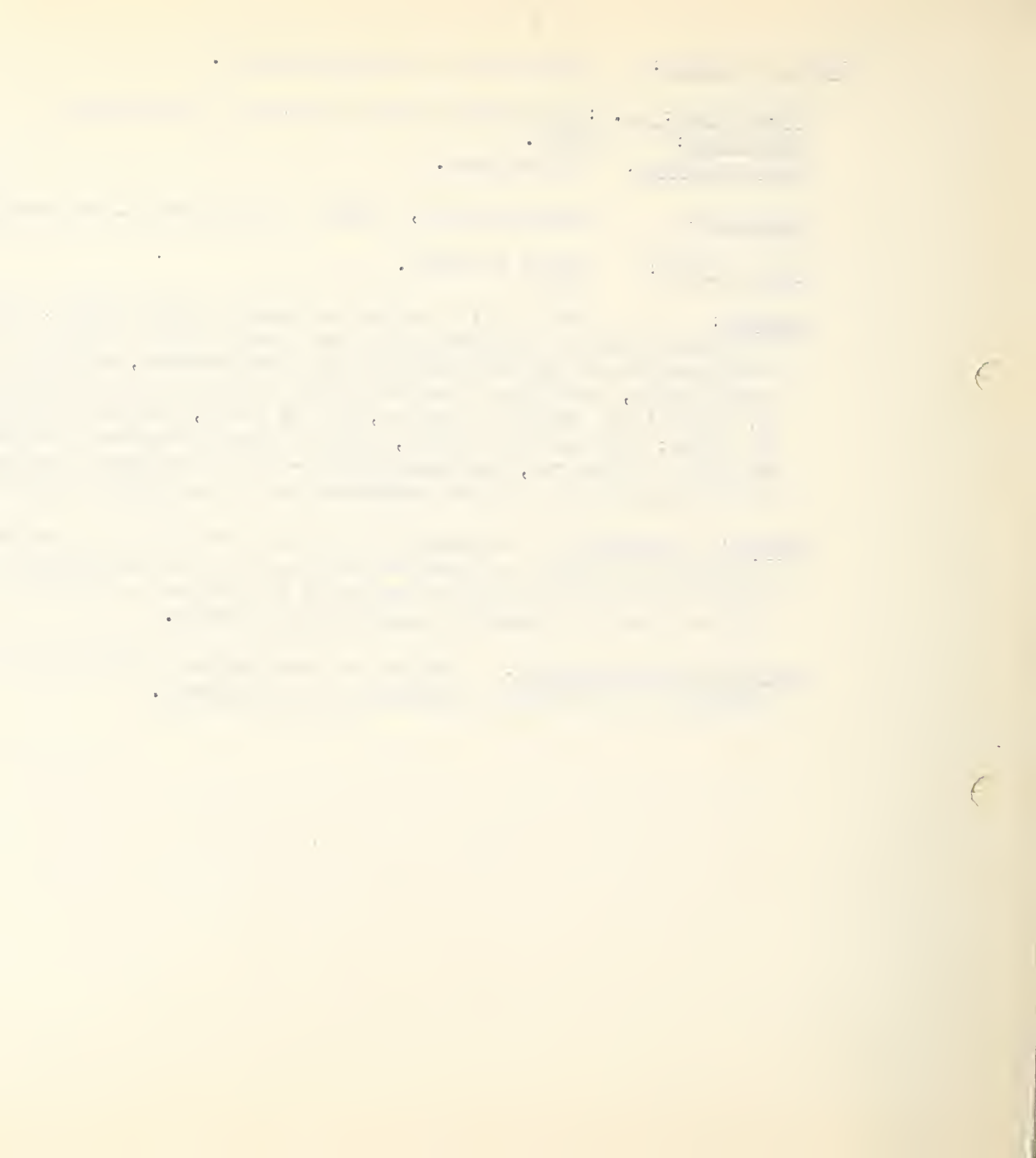
Authority: Appropriation, Bureau of Agricultural Engineering.

Cost of Work: \$1350 for 1933.

Results: While this project was only recently begun, there are certain benefits which it is hoped may be demonstrated by the use of unit heaters in greenhouses. Some of the advantages which may be proved for the unit heaters, are (1) relatively uniform temperature distribution, resulting from the effect of the fan in directing the heating air downward; (2) very little shading of crops, due to small, compact heating units with only a minimum of piping; (3) ease of control, through cheap and simple automatic-control devices and varying the speed of the fan, (4) flexibility - the temperature can be raised or lowered quickly, and (5) a gentle air motion advantageous to crop growth provided by the circulating fan.

Economic importance: The magnitude of the production of greenhouse crops in this country has been set forth under the project dealing with the investigation of greenhouse heating. Any improvement in the design or operation of the heating plant naturally results in a better crop and possible saving in cost to the operator.

Estimated annual saving: Project is just getting under way so that data permitting of an estimate of the possible saving are not available.



Title of project: Improvement of Farm Buildings.

Sub-project no.5: Research in farm structures.

Date begun: 1929.

Date completed: Field work completed in 1930, bulletin published in 1932.

Authority: As above.

Cost of work: Total cost \$8,000.

Results: The results of a survey of current research dealing with farm structures were reported to the Secretary of Agriculture in 1931 and published in Misc. Publication No. 133. In this report particular emphasis was placed upon (1) results accomplished through research, (2) current studies now being carried on, (3) present important problems, and (4) methods of coordinating the activities of the various State experiment stations in the field of farm structures research.

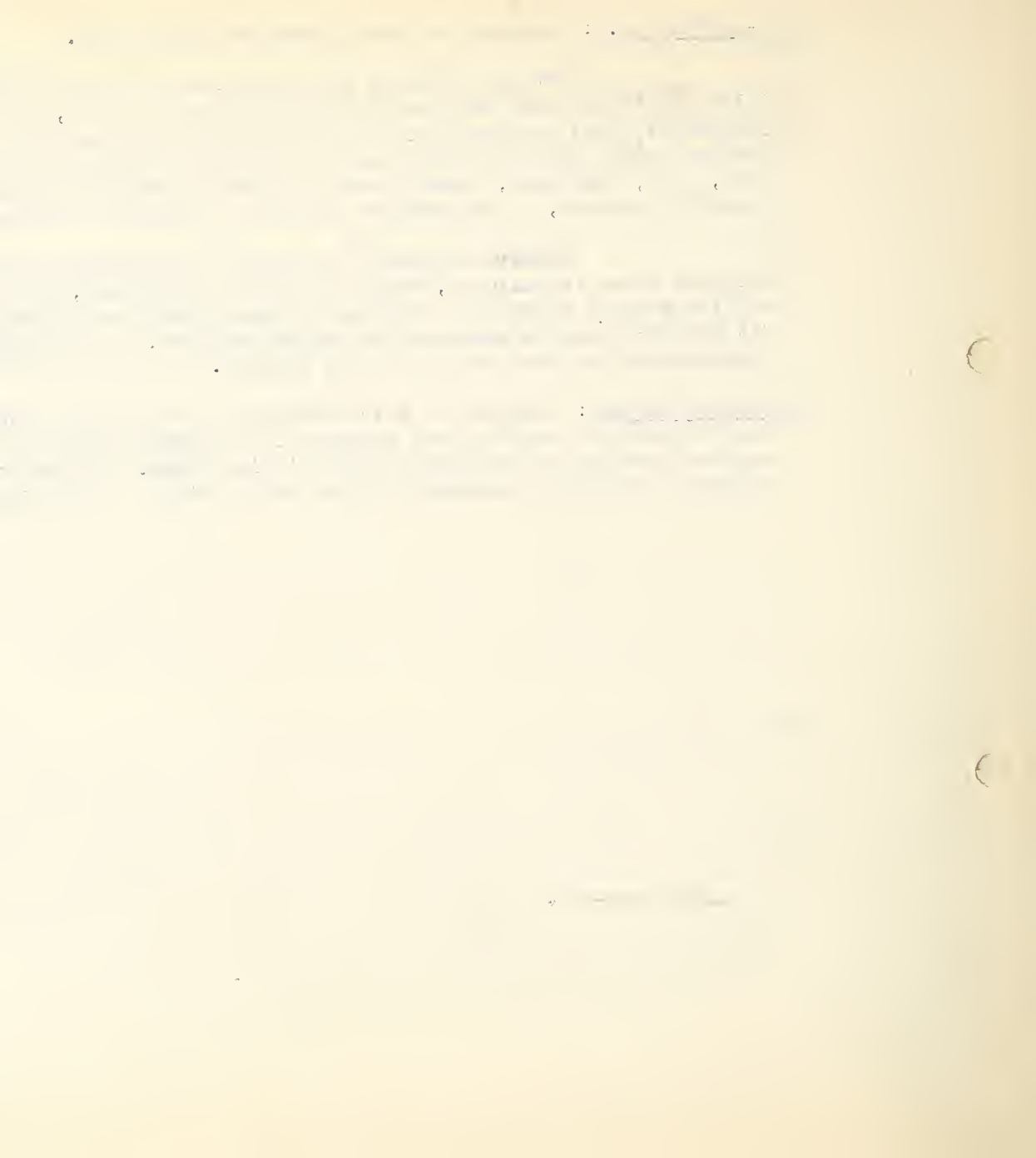
This survey assisted the Bureau, the State experiment stations, the technical committees of the American Society of Agricultural Engineers, and others, to organize their work so that undue duplications may be avoided, and attention directed to important problems which need study. As another result of this survey, the value of the building plan services of the various States has been greatly increased by the loan of approximately one thousand van dyke negatives of drawings prepared by this Bureau. These are used in making copies for local distribution. The State plan services are being further strengthened by a plan exchange arrangement, with the Bureau acting as the central coordinating agency, as discussed under Exchange Plan Service.

Economic importance: According to the 1930 census the total investment in farm buildings in the United States is nearly \$13,000,000,000. Land is the only larger item of farm investment. The amount ordinarily spent by American farmers upon the construction and repair of buildings amounts to roughly a million dollars per day. These large sums are spent on farm buildings because they are recognized as essential to successful farming, especially with livestock. Buildings definitely influence agricultural welfare. Aside from the fact that appearance, comfort, and convenience add to the pleasure of living and incidentally influence the productivity of the worker, there is a close relationship between buildings and the cost of production of farm products. Buildings definitely affect animal production. Stable temperatures influence milk flow and feed consumption. Egg production and bird comfort go together. Crops are conditioned and preserved by careful housing.

How can building be constructed with the greatest economy of labor and materials? What materials are most suitable for certain uses, and what treatment is necessary or advisable? What are weak points in construction and how may they best be corrected? What are the actual loads imposed upon the building? What provisions should be made to resist wind, fire, lightning, insect pests or other destructive agencies? These are a few of the pressing problems, which research in farm structures is trying to solve.

Farmers recognize the need for improvements and are continually experimenting with new ideas in building, some of which are very good, but independent experiments are costly and the results seldom are available outside their own neighborhood. To be of practical benefit research must be sponsored by public agencies, and is made much more valuable by coordination such as that sought by this project.

Estimated savings: The closer coordination and cooperation between the Bureau and the several State experiment stations has effected considerable savings through avoidance of duplication in research work and in preparation of building plans. We have no information on which to base a reliable estimate of monetary savings to the States and to farmers.



Title of project: Improvement of Farm Buildings.

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Sub-project: no.6: Farm building construction details.

Date begun: 1930.

Date completed: 1932.

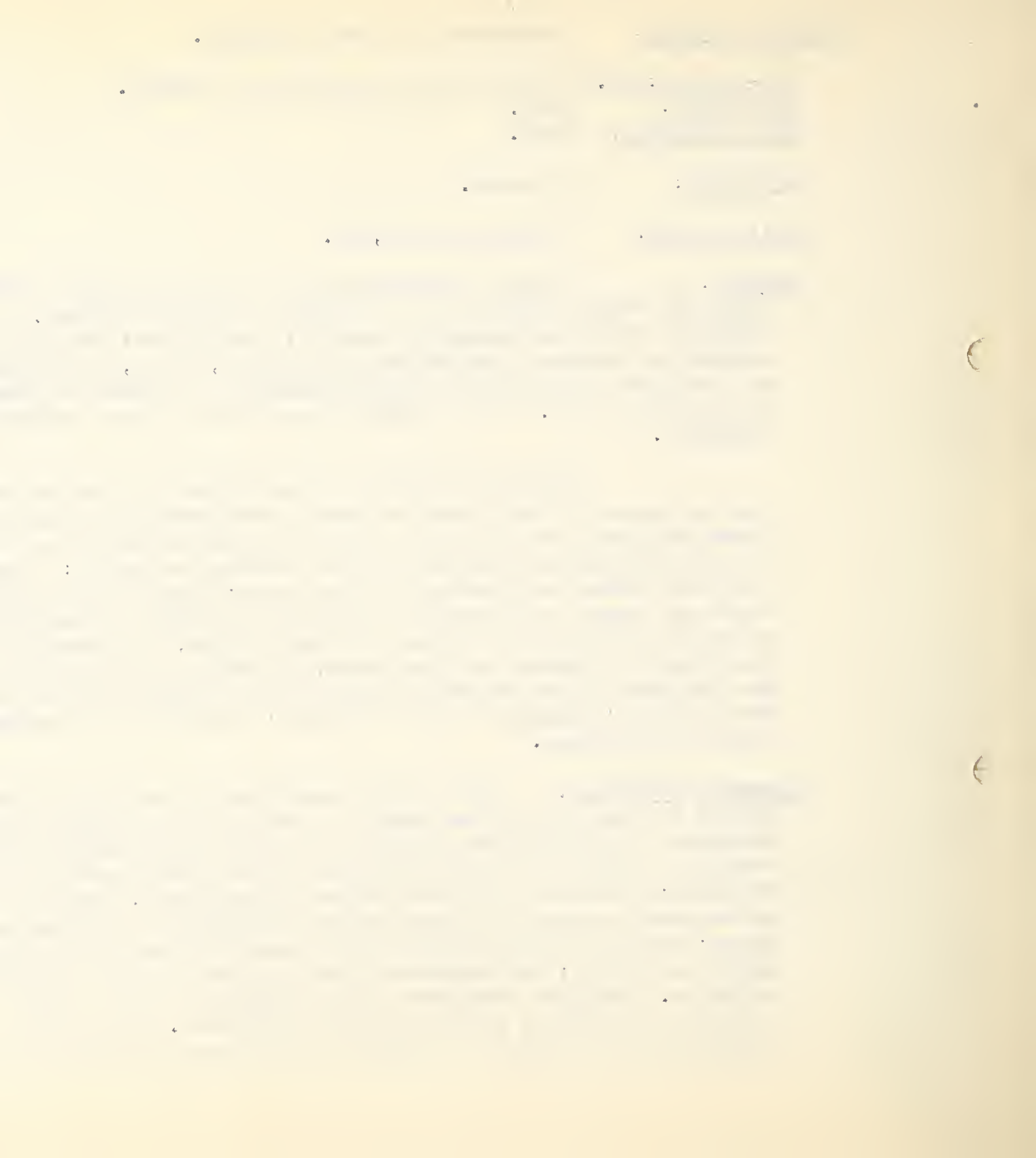
Authority: As above.

Cost of work: Average cost \$3,000.

Results: General observations and specific studies show that poor construction practices are often followed in the erection of farm buildings. As a consequence there are many buildings which lack adequate strength; proper provision against the deteriorating effects of weather; or adequate protection of the stock, crops, or equipment housed therein. Many are not arranged or equipped to best advantage with regard to time and labor saving in care of livestock or crops. On the other hand, there are some buildings which are unnecessarily expensive.

Improved methods of construction and better uses of materials and space have been developed by the Bureau to provide satisfactory and economical structures and equipment. These have been incorporated in plans for farm buildings and equipment distributed through the building plan service and in the following bulletins: Small Concrete Construction on the Farm; Sewage and Sewerage of Farm Homes; Beef Cattle Barns; Farmstead Water Supply, Farm Plumbing; Rammed Earth Walls for Buildings; Making Cellars Dry; Fire Protective Construction on the Farm; Farm Bulk Storage for Small Grains; Rat Proofing Buildings and Premises; Construction of Chimneys and Fireplaces; The Use of Logs and Poles in Farm Construction; Heating the Farm Home; Wind Resistant Construction; Bracing of Farm Buildings; Equipment for Farm Sheep Raising; Storage of Sweet Potatoes; Practical Hog Houses; Hog Lot Equipment; Poultry Houses and Fixtures.

Economic importance: A very large proportion of farm buildings and their appurtenances are erected by owners with farm labor or hired local builders, who are unfamiliar with the best practices of building construction or farm building requirements as determined by research. Adequate foundation for the structure; strong and economical framing; fire-retardent construction; insulation suited to climatic conditions; arrangement of space for safe, convenient and sanitary housing of livestock and preservation of crops; safe, durable and sanitary floors; safe and conveniently operated doors and windows; proper equipment for ease of handling animals and crops; are important factors affecting the usefulness and length of life of farm buildings. Building practices in any community change slowly except as new ideas are introduced by publications such as those listed above. The demand for information of the kind indicated on the part of the farming public has increased consistently from year to year.



In spite of the natural supposition that the farmers interest in structures would be greatly lessened because of the present economic conditions the demand for information is greater now than at any time since the beginning of the work in structures. The present demand for information may be accounted for, at least in part, by the fact that with low labor and material charges, farm buildings are now being erected at the lowest costs in years.

Estimated annual saving: Owing to the widely varying nature and extent of application of the information made available through this work an estimate of the savings affected is not possible.

Related work at State Experiment Stations: Work on farm building construction details is carried on by several State experiment stations, the nature of the work varying with local conditions.



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Title of project: Improvement of farm buildings. (continued)

Sub-project no. 7: Improvement of dairy barn design for south east Pennsylvania.

Date begun: 1929.

Date completed: 1931.

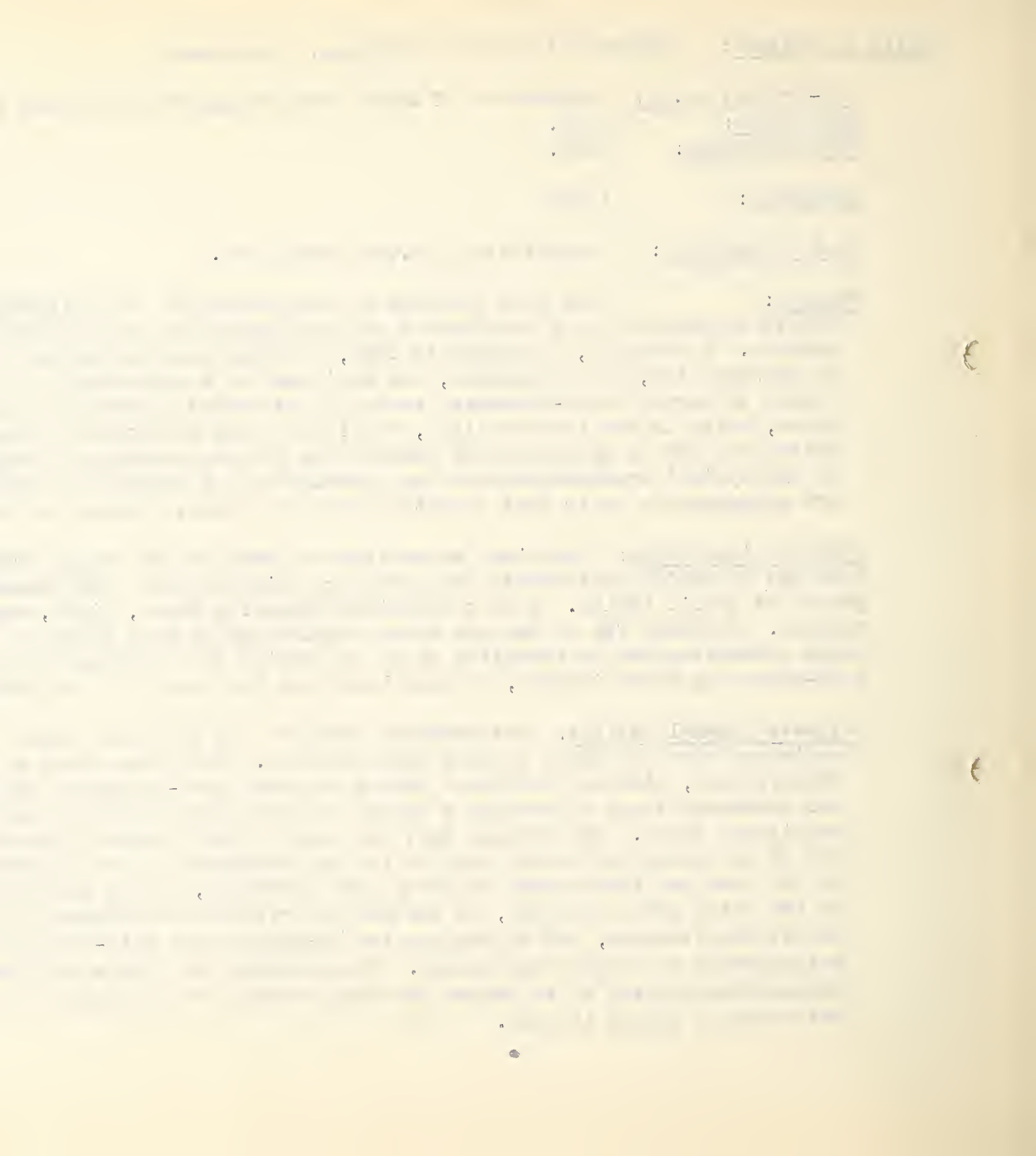
Authority: (Ibid)

Cost of the work: Approximately \$3,000 total cost.

Results: This work was done at the request of the Philadelphia Interstate Dairy Council and in cooperation with the Council and the Department of Farm Machinery of Pennsylvania State College. A circular, published in 1931, contains suggestions and recommendations for changes in construction, or arrangement, and equipment of a great many of the old bank dairy barns common to certain milk-producing areas of the Middle Atlantic and North Central States and which, owing to the lack of light, ventilation and sanitation do not comply with housing requirements set up by regulatory authorities in large centers of milk consumption. Changes in the typical arrangements and the installation of modern time and labor-saving equipment are suggested in order that operating and maintenance charges may be reduced.

Economic importance: Municipal authorities in many of the larger centers of milk consumption have set up rigid requirements for producers shipping milk into those centers in order to safeguard the public health. Such regulations prescribe clean, light, sanitary stables and healthy animals. Although few of the old barns studied can be made ideal at a reasonable cost, a very large proportion may be remodeled so as to provide the principal requisites of an acceptable milk-producing establishment, at much less than the cost of a new barn.

Estimated annual savings: The monetary value of the work done under this project can not be estimated upon the basis of data now available. While the study was confined to southeastern Pennsylvania, similar conditions obtain in other milk-producing sections of the country and the recommendations offered as a result of this work apply with equal force wherever such conditions exist. The savings that may result from a general adoption of the recommendations are of an intangible nature and lie in the prolonged life of altered and repaired structures, in the time and labor saved in dairy barn operation, in the improved health and productiveness of the dairy stock involved, in the greater returns to producers by reason of compliance with market requirements, and in the greater freedom of the milk-consuming public from disease attributable to a poor milk supply. The assurance of a safe milk supply tends to increase its consumption as well as to reduce the high prices often charged for good quality milk where the ordinary supply is poor.



Title of project: Improvement of Farm Buildings. (continued)

Sub-project no. 8: Domestic oil burners.

Date begun: 1924.

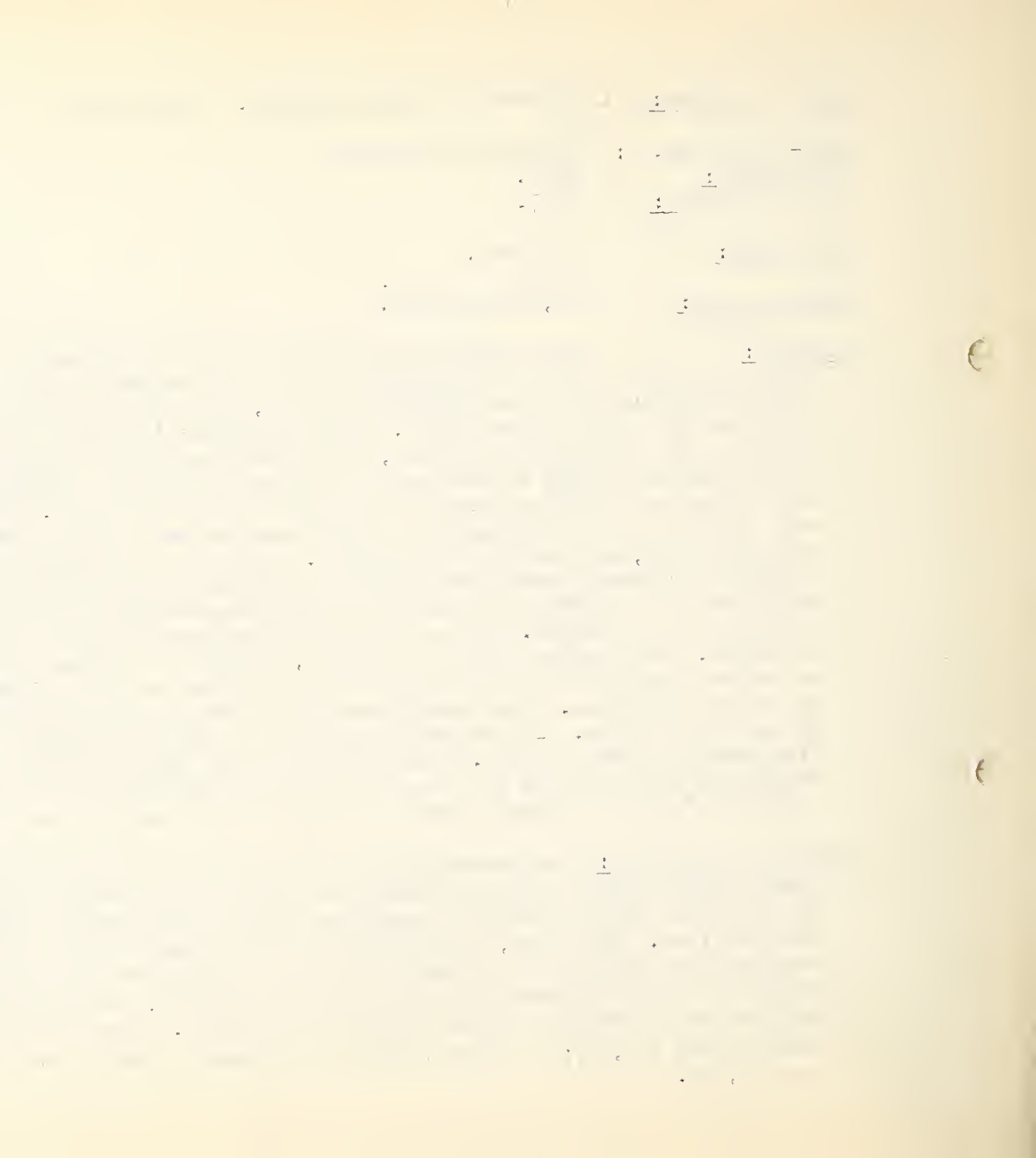
Date completed: 1927.

Authority: As above.

Cost of work: \$5,500 per year.

Results: When domestic oil burners were first placed on the market prospective purchasers sought information from the Department as to the merits of different types and makes offered, the characteristics of oils best adapted as fuel, the extent of fire risk, and comparison of cost of operation of oil with other fuels. From tests made in cooperation with the Bureau of Home Economics and study of private installations, the Division of Agricultural Engineering was able to indicate the performance that might be expected of the several types of burners available, adaptability of existing heating plants to oil burners and estimated cost of operation. It was found that oil burners were well suited to the requirements of many homes because of their convenience, freedom from handling coal and ashes, and ease of heat control. The cost of changing from coal to oil heating and a possible increase in operation cost was often not a serious consideration if the existing plant was adaptable to oil burning and the operative characteristics of the oils in the different types of burners were understood. It was found that the grade of oil for best results varied with the type of burner. The atomizer types of burners, generally equipped with full automatic control, proved to be less exacting as to the type of fuel required and less given to smoking and sooting because of better combustion. The tests showed that there was no material difference in the efficiency of the better makes. It was found advisable to warn prospective purchasers with respect to the fire risk of unsafe burners. The relative costs with respect to the number of gallons of oil equivalent in heat value to a ton of coal was worked out so as to enable the user to obtain an estimate of operating costs when the prices of coal and oil were known.

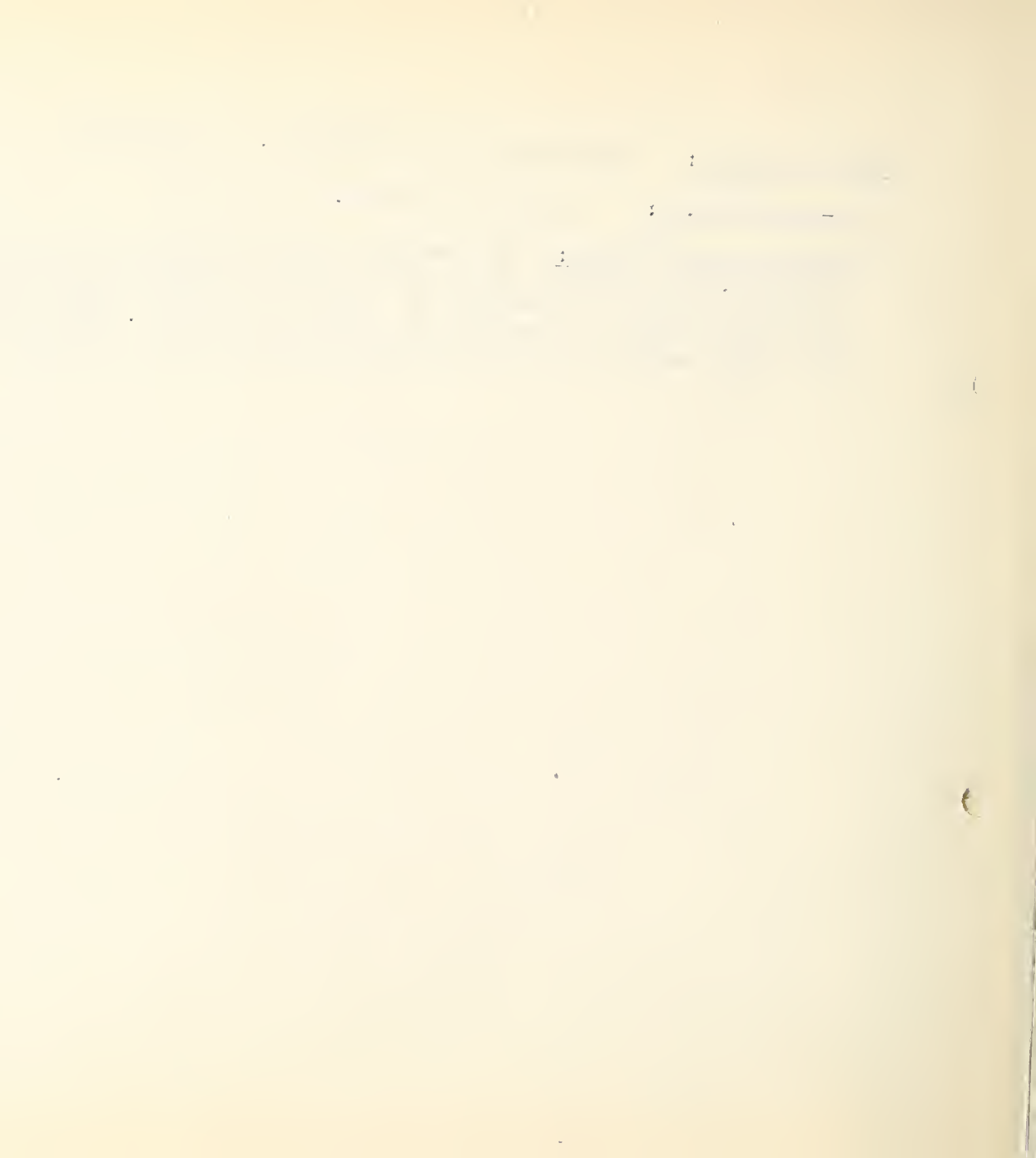
Economic importance: The economic value of the work lies in the aid which it has been possible to give to many farmers and city dwellers desirous of improved living conditions at the same time guarding them against unwise expenditures for unsatisfactory equipment which would constitute an economic loss. Similarly, manufacturers of oil burners have profited by the findings of the project and have instituted research investigations of their own resulting in greatly improved burners which, because of their increased efficiency and reliability, have found a greater market and added to the comfort and convenience of many farm and city homes. Installations of domestic oil burners during 1931 totaled 103,997; the total number of burners in use in the United States, as of December 31, 1931, was 773,400.



Title of project: Improvement of Farm Buildings. (continued)

Sub-project no. 8: Domestic oil burners. (continued)

Estimated annual savings: The monetary saving attributed to the results of this work can not be estimated. The principal savings lie in the aid extended to the buyer in selection of suitable equipment and the discontinuance of some models and improvement of others by the manufacturer. No other similar work has been done by a public institution. The publication of these results have been widely sought and constitute the principal source of information on this subject.



Title of project: Improvement of Farm Buildings. (continued)

Sub-project no. 9: Greenhouse heating.

Date begun: 1929.

Date completed: 1932.

Authority: As above.

Cost of work: \$1,500 per year.

Results: A survey made in eastern and central states showed that while greenhouse installations by qualified specialists were almost uniformly satisfactory, there are a great many systems installed by local plumbing and heating firms or by owners themselves which were not properly installed, do not function efficiently and in other ways do not meet the requirements of a greenhouse heating plant. A circular published in 1932 intended as an aid to owners and heating contractors in designing and improving greenhouse heating plants. It presents engineering data pertaining to the several types of heating systems in use and practical information with regard to the layout and operation of modern heating systems. Observations made of conditions in many commercial houses led to the setting up of two projects, one on the use of unit heaters as a means of attaining greater efficiency and economies, and one on the sterilization of greenhouse soils, the present methods being expensive and of questionable efficiency.

Economic importance: The production of greenhouse crops in the United States is an important industry because of the demand for high quality vegetable and floral products that can be grown in the modern greenhouse. The quality of locally grown greenhouse crops permits of competition with those grown outdoors in warm climates and shipped long distances to northern markets. The value of the crops grown under glass in the United States, according to the last available census figures (1919) was more than \$77,000,000, and there has been an expansion of the industry since that time. Any decrease in operating costs or improvement in the maintenance of conditions most favorable to the crops grown should benefit the industry, and result in better products at lower prices.

Estimated annual saving: The savings that might be effected by improved heating practices depend upon the extent to which improvements should be made in houses of many sizes and varying states of present efficiency. The circumstances therefore do not admit of an estimate of savings.



Title of project: Improvement of Farm Buildings. (continued)

Sub-project no. 10: Cheese factories and creameries.

Date begun: 1928.

Date completed: 1929.

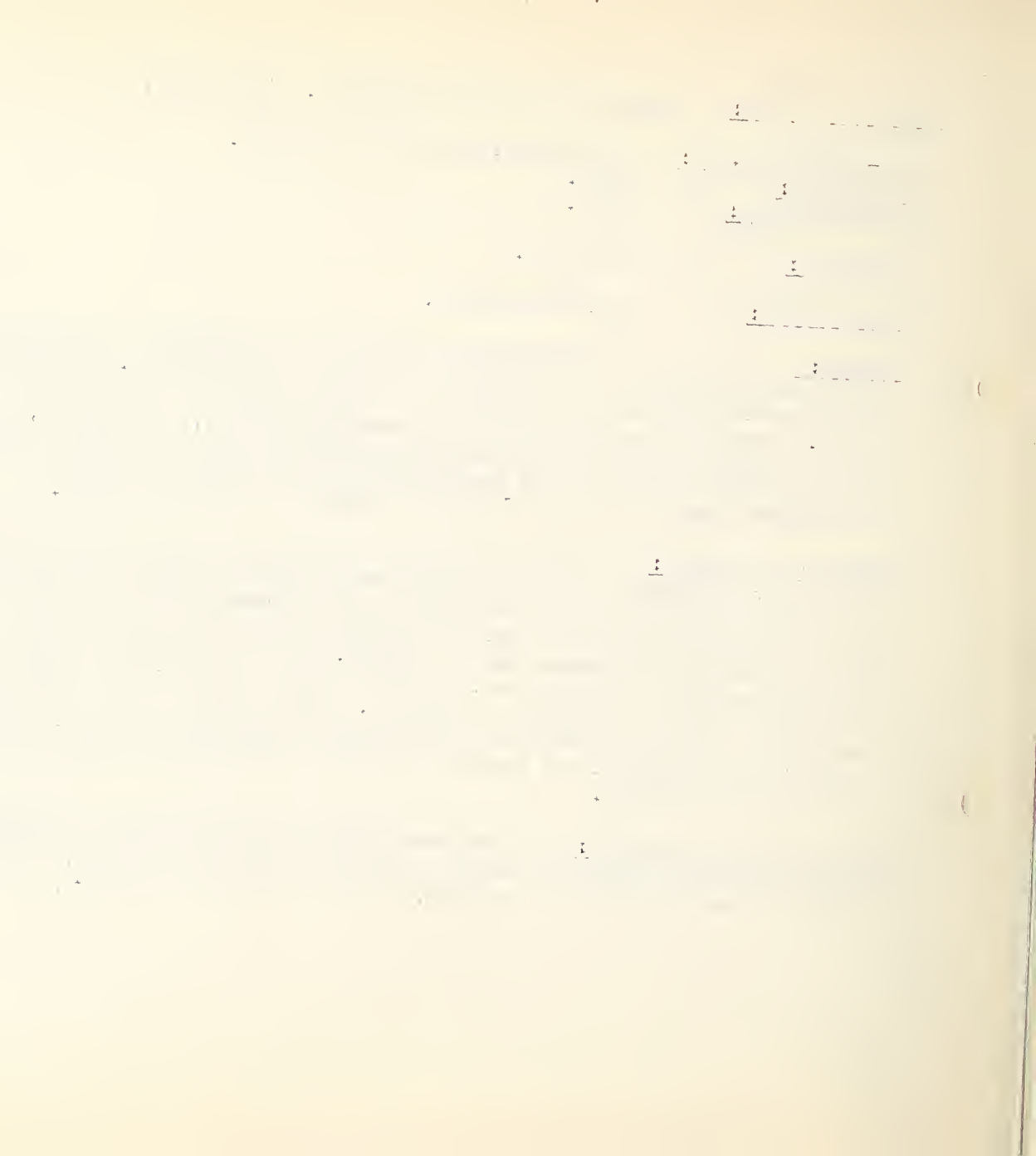
Authority: As above.

Cost of work: \$1,250 per year.

Results: Complete plans and bills of materials for several cheese factories and creameries of various capacities were prepared for general distribution. The designs were based upon data as to requirements furnished by the Bureau of Dairy Industry in cooperation with which the work was undertaken. The plans are suggestive of space requirements, arrangement, construction, and equipment for plants of approximately the capacities indicated and are intended as aids to cooperative organizations and individual firms in rural localities in the erection of new buildings or the remodeling of existing structures essential to the efficient conduct of such enterprises.

Economic importance: The manufacture of cheese and butter is an industry of considerable size and importance concerned with the manufacture of food for human consumption. As with any other such product it is highly desirable that the methods and processes employed shall be such as to insure good quality. From the manufacturing standpoint it is also desirable that the plant and equipment shall be efficient, and economical in operation and management. The information obtained by the Bureau of Dairy Industry, through research investigations, affecting the physical requirements of such plants, is most useful in the form of plans for complete buildings. These plans enable those in the industry to build with assurance of sound construction, convenient arrangement of plant, space sufficient for the efficient conduct of operations, and equipment of types and capacities best suited to the production of cheese and creamery products.

Estimated annual savings: As the investigation was primarily a project of the Bureau of Dairy Industry in the engineering phase of which the Bureau of Public Roads was asked to cooperate, this Bureau does not have the economic data necessary to an estimate of savings.



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BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF STRUCTURES

Title of project: Storage and transportation of farm products.
Date begun: 1922.
Date completed: In progress.

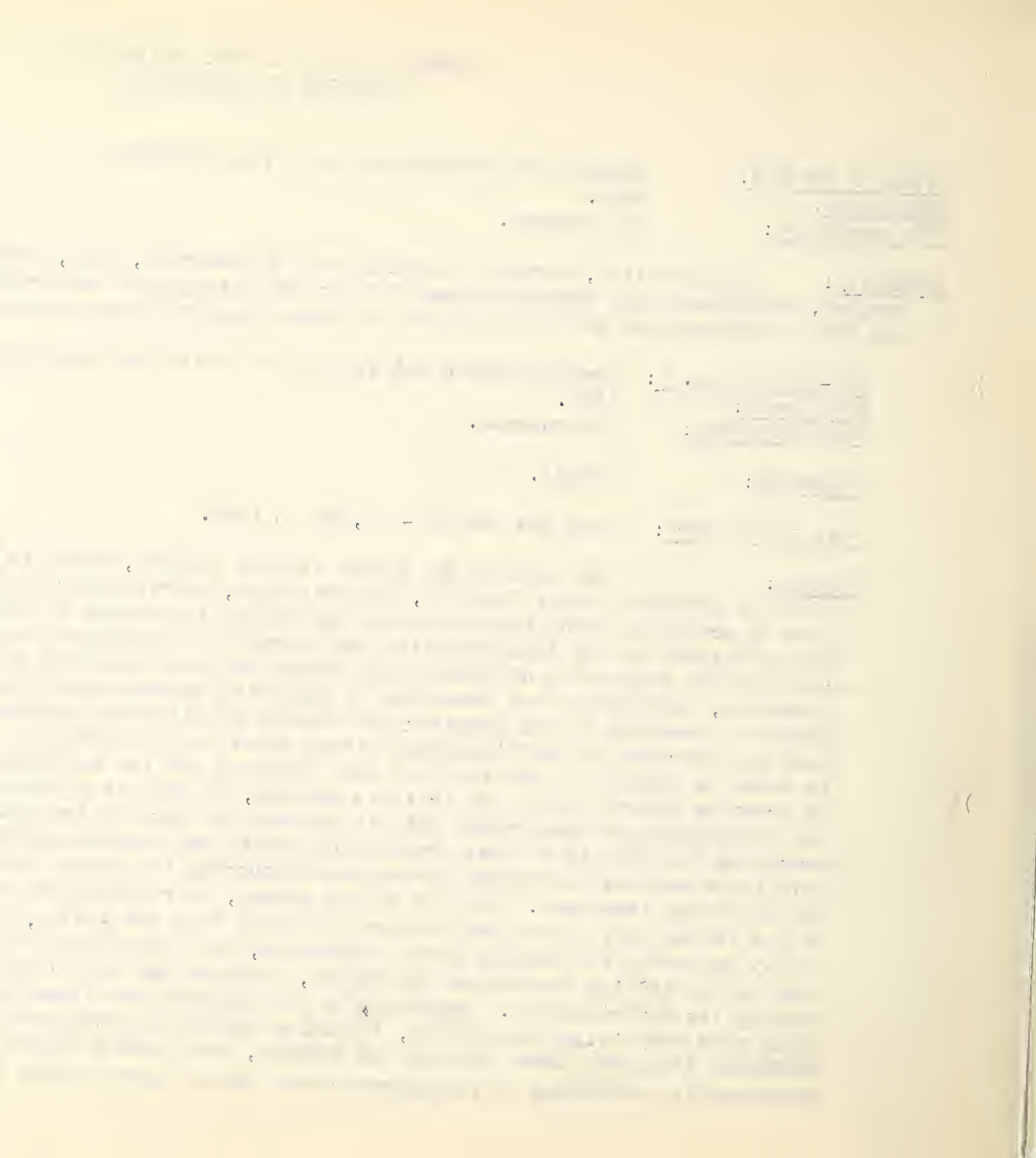
Authority: Appropriation, Bureau of Agricultural Engineering, 1933, under an item "For investigations, experiments and demonstrations *** upon the design and construction of farm buildings and their appurtenances and of buildings for preserving and storing farm crops."

Sub-project no. 1: Transportation and storage of fruits and vegetables.
Date begun: 1922.
Date completed: In progress.

Authority: (Ibid).

Cost of the work: Cost has varied - \$7,000 in 1933.

Results: The part of the Bureau in this project, which is carried on in cooperation with the Bureau of Plant Industry, and railroads, refrigerator car companies, and shippers, lies in providing means for obtaining data sought in efforts to bring about greater economy and efficiency in the transportation and storage of perishable fruits and vegetables. This involves the adaptation of existing equipment and the designing of apparatus and methods for producing, maintaining and observing or measuring experimental conditions. In the early phases of the work it was necessary to develop considerable equipment of unique character, such as apparatus for refrigerating citrus trees in the grove and freezing fruit on the tree in order to permit a close study of such freezing and the development of methods for detection of freezing injury before the fruit is shipped, as well as a variety of special equipment for the measurement of temperature and air movement in cars in transit. Special instruments for measuring the amounts of heat produced by fruits and vegetables in storage, and very low air velocities such as convection air currents occurring in storage rooms or refrigerator cars are now being developed. Studies of the effect, on refrigerator car insulation, of the use of ice in the body of the car in direct contact with the lading, which these experiments found highly desirable for certain green vegetables, have shown that in the older types of cars, water from the melted ice penetrated the floors, reducing the effectiveness of the insulation and causing its deterioration. Adoption by refrigerator car lines of car construction features which make body icing practicable, including effective waterproofing of car floors and use of depressed drip pans under the end ice bunkers, have been a direct outcome of this project. A considerable percentage of refrigerator cars now in service have been already so equipped.



Title of project: Storage and transportation of farm products.

Sub-project no. 1: Transportation and storage of fruits and vegetables (continued).

Work done by State Experiment Stations: Investigations of special problems in the storage of certain crops are carried on at a number of State experiment stations including California, Idaho, Montana, Colorado, Iowa and Pennsylvania, and technical storage studies are conducted by Pennsylvania. Transportation investigations in general are concerned with interstate shipments of perishables and no investigations of this character are conducted by any of the State experiment stations.

Economic importance: The transportation and storage of perishable food products is, next to the actual production of crops, the most important process in the feeding of the nation. This project has made essential and important contributions to the building up of the existing nation-wide system of all-year distribution of fruits and vegetables. Improvements in methods and facilities growing out of the information gained through this joint project have been a material factor in making available to the average citizen an abundant and continuous supply of these necessary and wholesome foods and have had an important effect on the food habits of the nation. Great progress in this line has been made, but losses due to deterioration in transit and storage are still in evidence and the development of economical means of further reducing them is highly desirable.

Estimated annual savings: The project is essentially one for investigation by the Bureau of Plant Industry. The work of this Bureau, in connection with the engineering problems incident to the investigation, is essential to both the determination of cause and effect and the development of remedial measures. It is, however, so intimately associated with the physiological phase of the work that it is not feasible to estimate its share in any annual saving effected.

Title of project: Storage and transportation of farm products. (continued).

Sub-project no. 2: Relation of storage house construction and management to storage losses of white potatoes.

Date begun: Fiscal year 1926. Discontinued 1928 to 1931. Work resumed in fiscal year 1932

Date completed: In progress.

Authority: (Ibid)

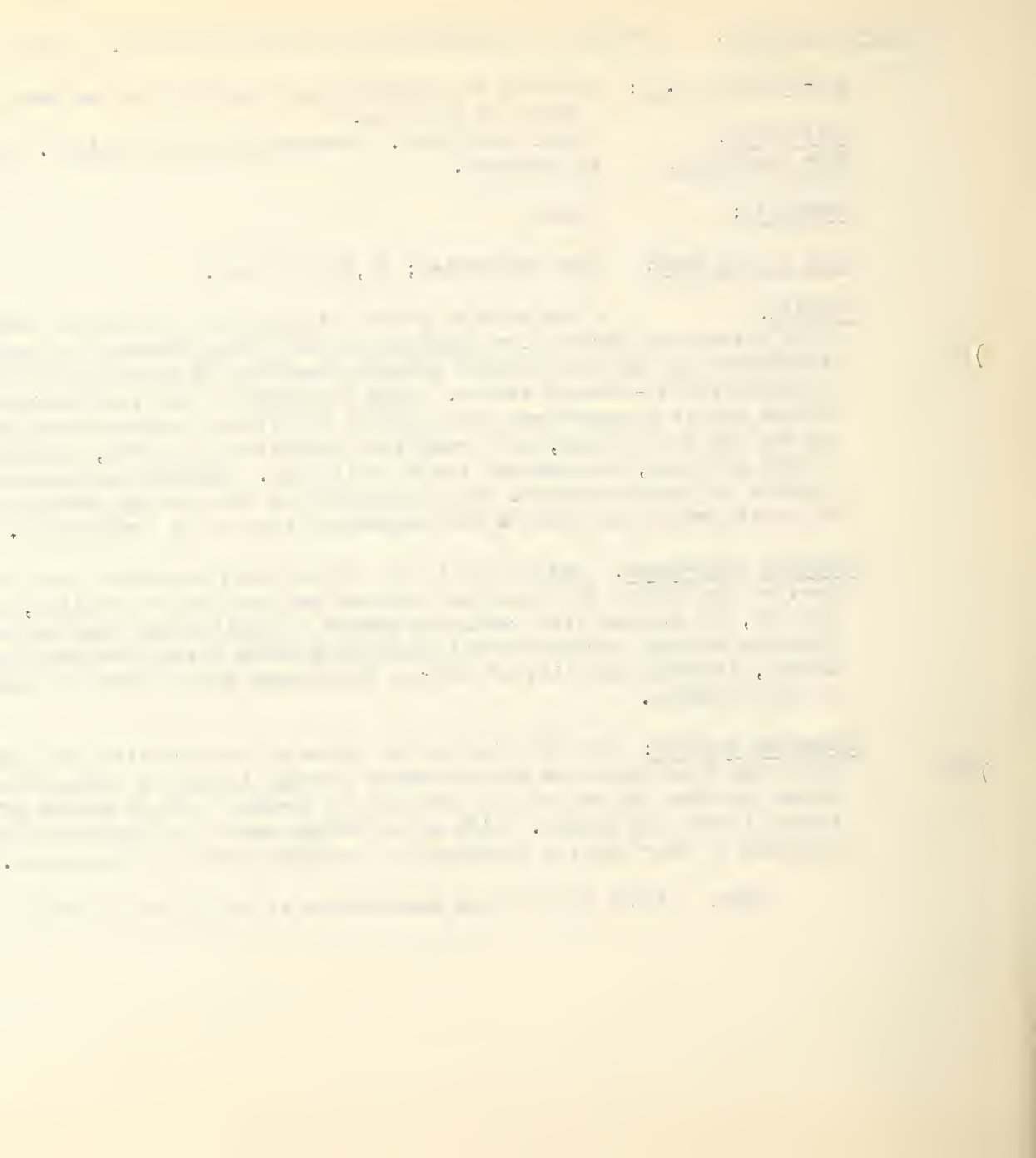
Cost of the work: Cost has varied; \$6,500 in 1933.

Results: A new type of potato storage house developed and recommended by the cooperating Bureaus of Agricultural Engineering and Plant Industry is replacing older types of structures in the heavy potato shipping sections of Maine and is influencing design in other northern potato-growing states. Warm construction and ventilation provided in these new houses enable temperatures and moisture conditions to be controlled much more readily than in the old type houses, with resulting reduction of losses, improvement in quality of the stored potatoes, and longer life of buildings. Improved methods of handling now under trial promise to further improve the quality of the potatoes by reducing mechanical injury. A bulletin presenting results and recommendations is in preparation.

Economic importance: The potato is one of our most important food crops, but a considerable part of the supply reaching the consumer has been either chilled, overheated, sprouted or bruised, in storage with resulting damage to quality and food value. The adoption of the improved storage structures and handling methods being developed by this project will reduce losses, increase the life of storage structures and improve the quality of potatoes delivered to the consumer.

Estimated savings: The adoption of the types of construction and methods of handling potatoes resulting from this work should reduce average losses in storage to 5 per cent or less of the stored portion of the crop as compared to present average losses of about 10 per cent. Much larger losses are common. Life of buildings should be greatly increased, and the amount of potatoes of poor quality reaching the consumer should be decreased.

Note: Little work of the same nature is being done by State experiment stations.



BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF STRUCTURES

Title of Project: Storage and Transportation of Farm Products.

Sub-project No. 3: Grain storage.

Date begun: 1928

Date completed: In progress.

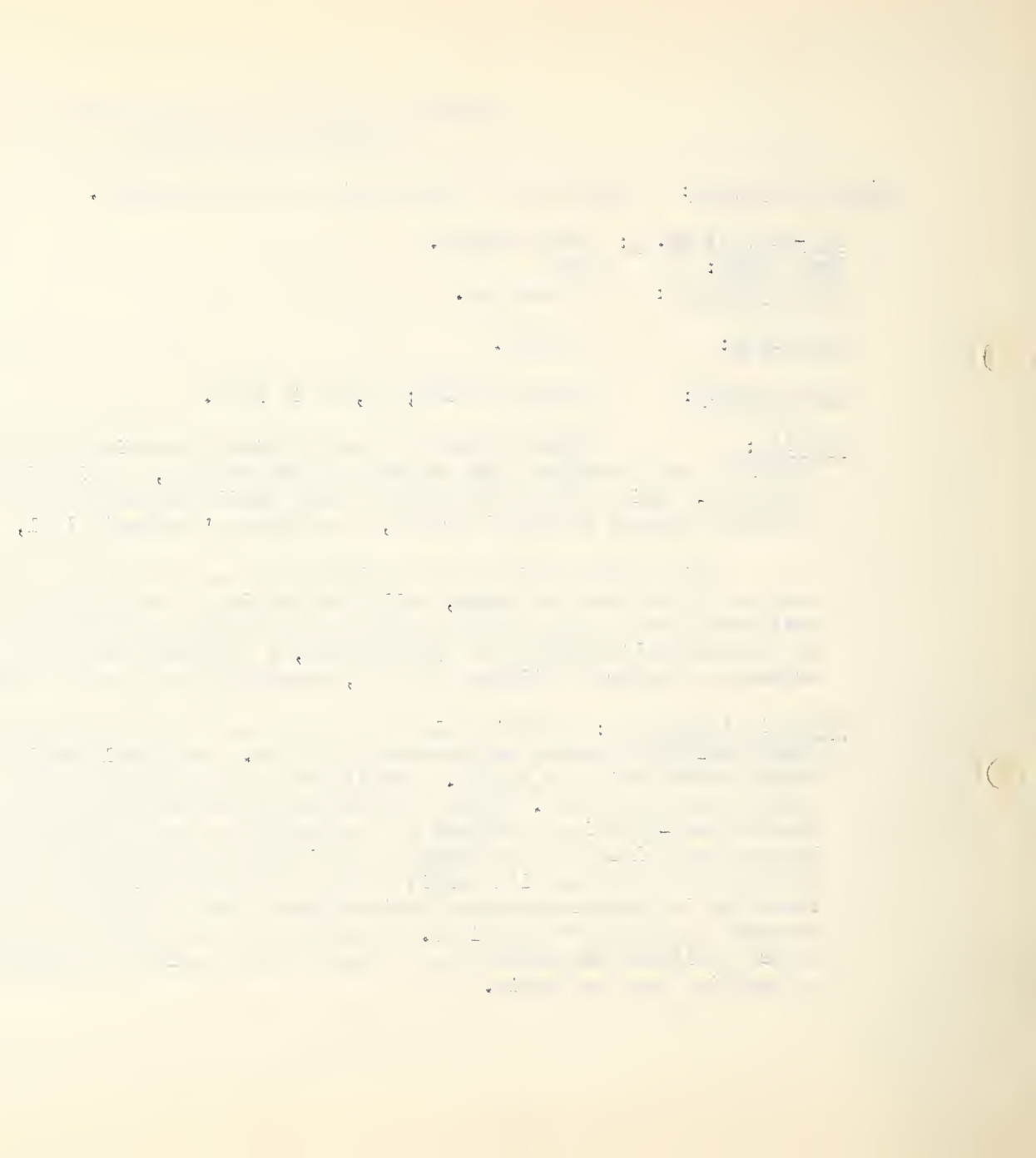
Authority: As above.

Cost of work: Cost has varied; \$3,000 in 1933.

Results: Valuable data has been obtained regarding the most satisfactory types of corncribs and granaries with respect to construction, ventilation, ratproofing, and handling equipment. This information has been made available to farmers in Farmers' Bulletin 1636, Farm Bulk Storage for Small Grains, and Farmers' Bulletin 1701, Corncribs for the Cornbelt.

This investigation also developed data as to actual vertical and horizontal pressures exerted by ear corn on floors, walls and bracing of corncribs up to 24 feet in height. The data shows that in high cribs 50 per cent or more of the weight of the corn may be supported by the side walls instead of by the floor, a fact not previously recognized, as witnessed by numerous structural failures of cribs, especially large cribs filled by mechanical elevators.

Economic importance: Approximately eighty per cent of the corn crop and large quantities of small grains are stored and consumed on farms. Much small grain is stored temporarily on farms before moving to market. Profits of the crop depend upon the amount saved as well as upon the amount raised. Types of cribs and granaries and methods of construction, ventilation and rat-proofing advocated by the Bureau as the result of this project will minimize losses from molding or rat damage of grain and result in increased life of the buildings. The data on pressures will permit of more accurate designing of grain storage structures, resulting in greater assurance against losses due to failure of structures, and greater economy in the use of materials. Adoption of these recommendations by farmers will also reduce accidents to persons due to unsafe construction and equipment and unsafe practices in handling corn and grain.



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Estimated Savings: No information is available on which to base a reliable estimate of savings.

Comparable work by State experiment stations: Special phases of storage of corn are being investigated at the Ohio, Illinois, and Iowa experiment stations. The Kansas experiment station is investigating the drying of grain in bins of different materials.



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BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF STRUCTURES

Title: Storage and Transportation of Farm Products.

Sub-project No. 4: Sweet Potato Storage.

Date begun: 1917

Date completed: 1929.

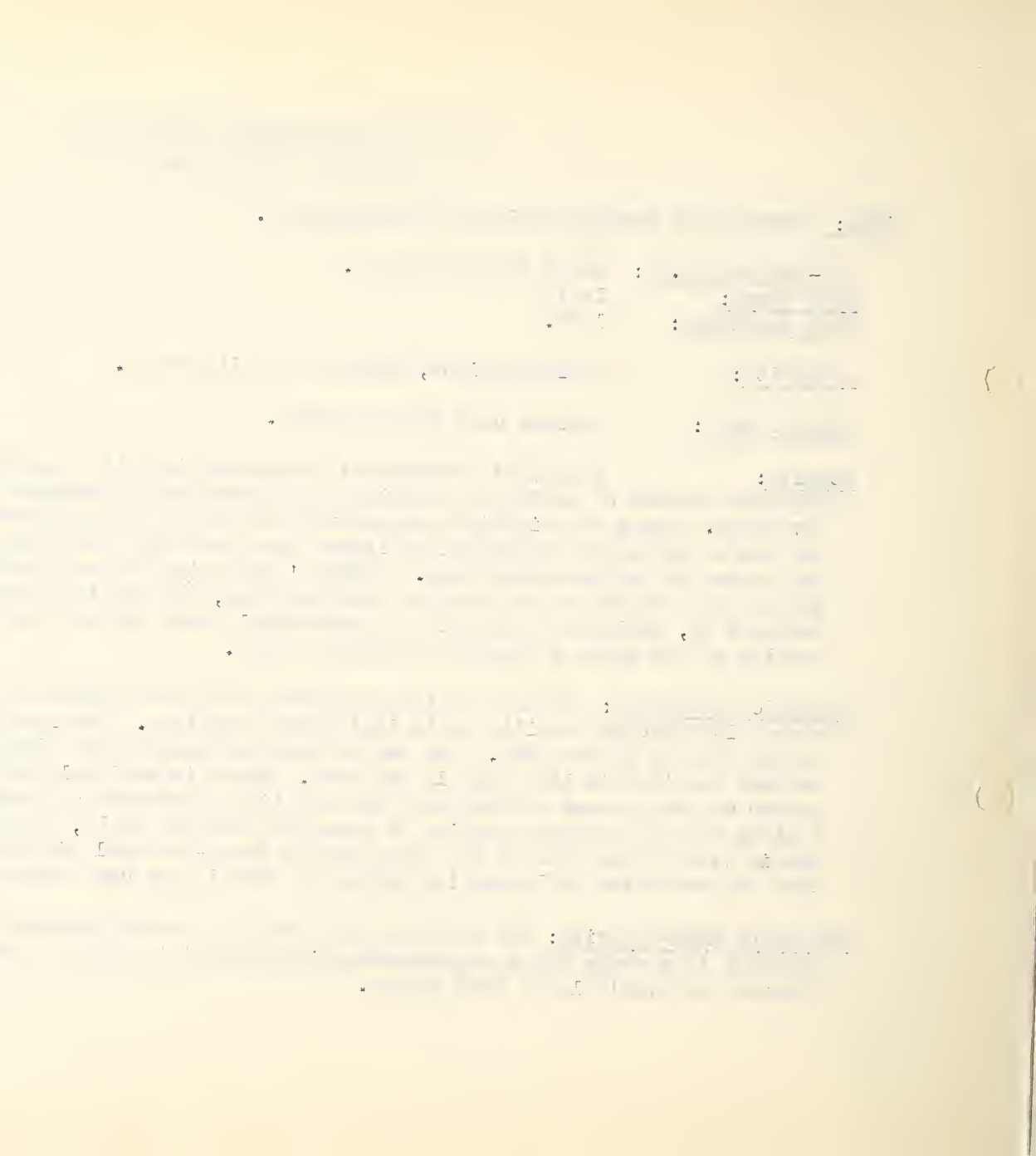
Authority: Appropriations, Bureau of Public Roads.

Cost of work: Average cost \$800 per year.

Results: A project carried out in cooperation with the Bureau of Plant Industry. Improved methods of curing and storing sweet potatoes in farm and trackside storages were developed. Means of maintaining approximately uniform temperature and humidity without the use of expensive mechanical equipment were found and provided for in a series of plans for houses of various capacities. Farmers' Bulletins 970 and 1442, Sweet Potato Storage, present the results of the work on farm storages, and Virginia Truck Experiment Station Bulletin 69, Design and Operation of Commercial Sweet Potato Storage Houses, presents the results of the work on community storage houses.

Economic importance: Prior to this undertaking the sweet potato crop was very generally stored in trenches or hills or in inadequate buildings. The loss through rot and disease ran as high as 50 per cent. The use of storage based on the plans prepared in the Division reduced the loss to less than 10 per cent. There is available no data as to the actual number of such houses erected nor the quantity of potatoes so stored but it is known that a large number of houses ranging in capacity from 500 to 15,000 bushels, are in operation and in view of the size of the sweet potato crop - several million bushels - it is obvious that the reduction of losses in storage by even 10 per cent means large annual savings.

Estimated annual saving: The work has resulted in a marked decrease in the loss of sweet potatoes in storage and a corresponding improvement in product marketed, but no definite figures are available in this Bureau.



BUREAU OF AGRICULTURAL ENGINEERING
Division of Structures

Title: Storage and Transportation of Farm Products.

Subproject No. 5: Mechanical refrigeration on dairy farms.

Date begun: 1930

Date completed: In progress. To be completed June 1933.

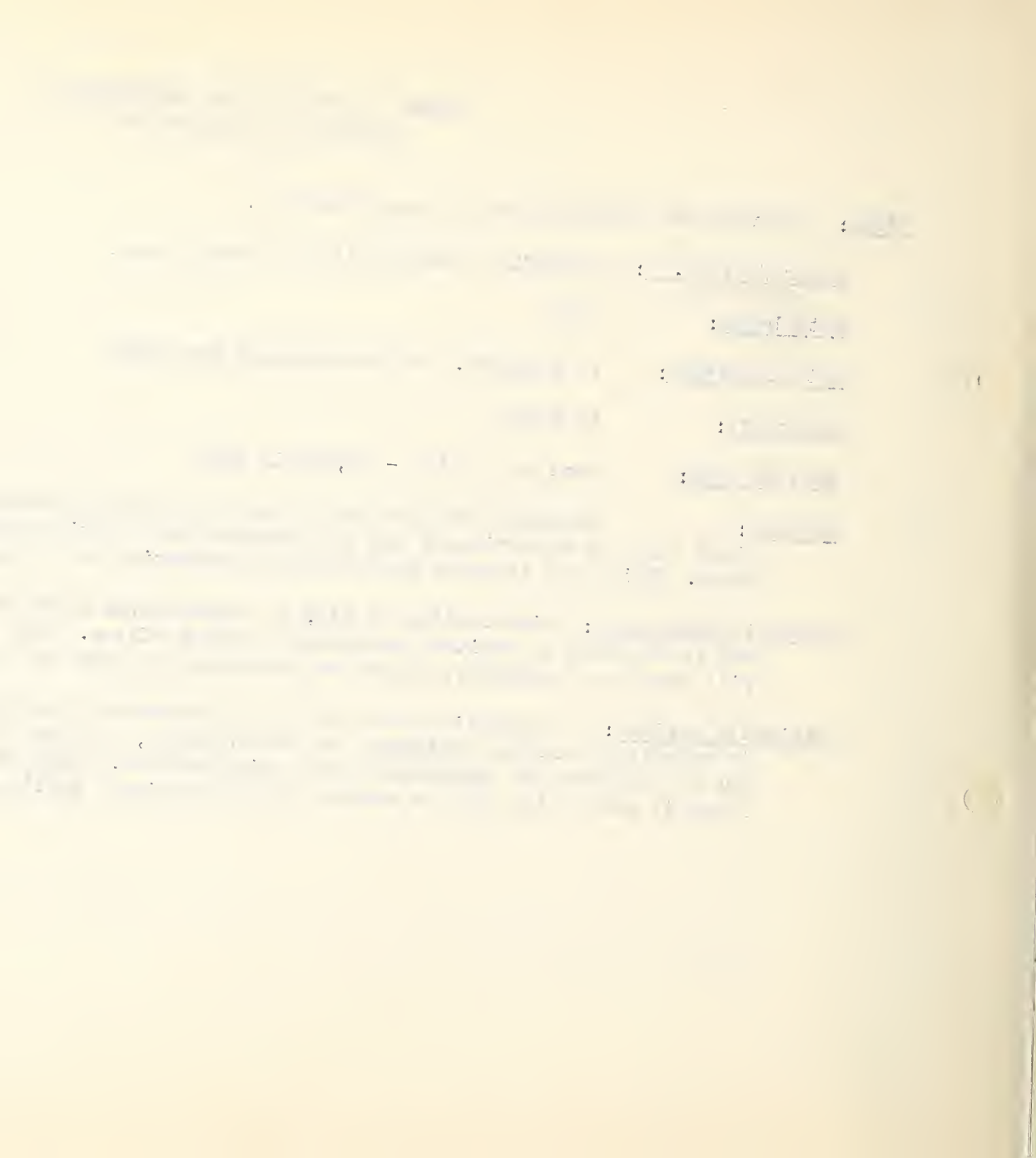
Authority: As above

Cost of work: Cost has varied - \$1,090 in 1933

Results: Data were secured by the Bureaus of Agricultural Engineering and Dairy Industry in field tests of electrically and ice operated milk cooling tanks and refrigerators of various types. This data is being worked up and manuscript for a bulletin is being prepared.

Economic importance: Quick cooling of milk to temperatures below 50° aids in maintaining high quality, and is required by sanitary ordinances of many cities. The information secured in these studies will show the comparative costs and advantages of iced and electrically operated coolers for milk.

Estimated savings: Information which will be presented as the result of this study will aid farmers in selecting suitable equipment for cooling milk, and help them to avoid unwise purchase or losses due to rejection of improperly cooled milk markets. Work on mechanical refrigeration for dairy farms is also being done by several State Experiment Stations.



Title of project: Storage and transportation of farm products. (continued)

Sub-project no. 6: The effect of cooling pipe location, cooling surface area, and refrigerant temperature on temperature distribution and relative humidity of cold storage rooms.

Date begun: 1928.

Date completed: 1932.

Authority: (Ibid)

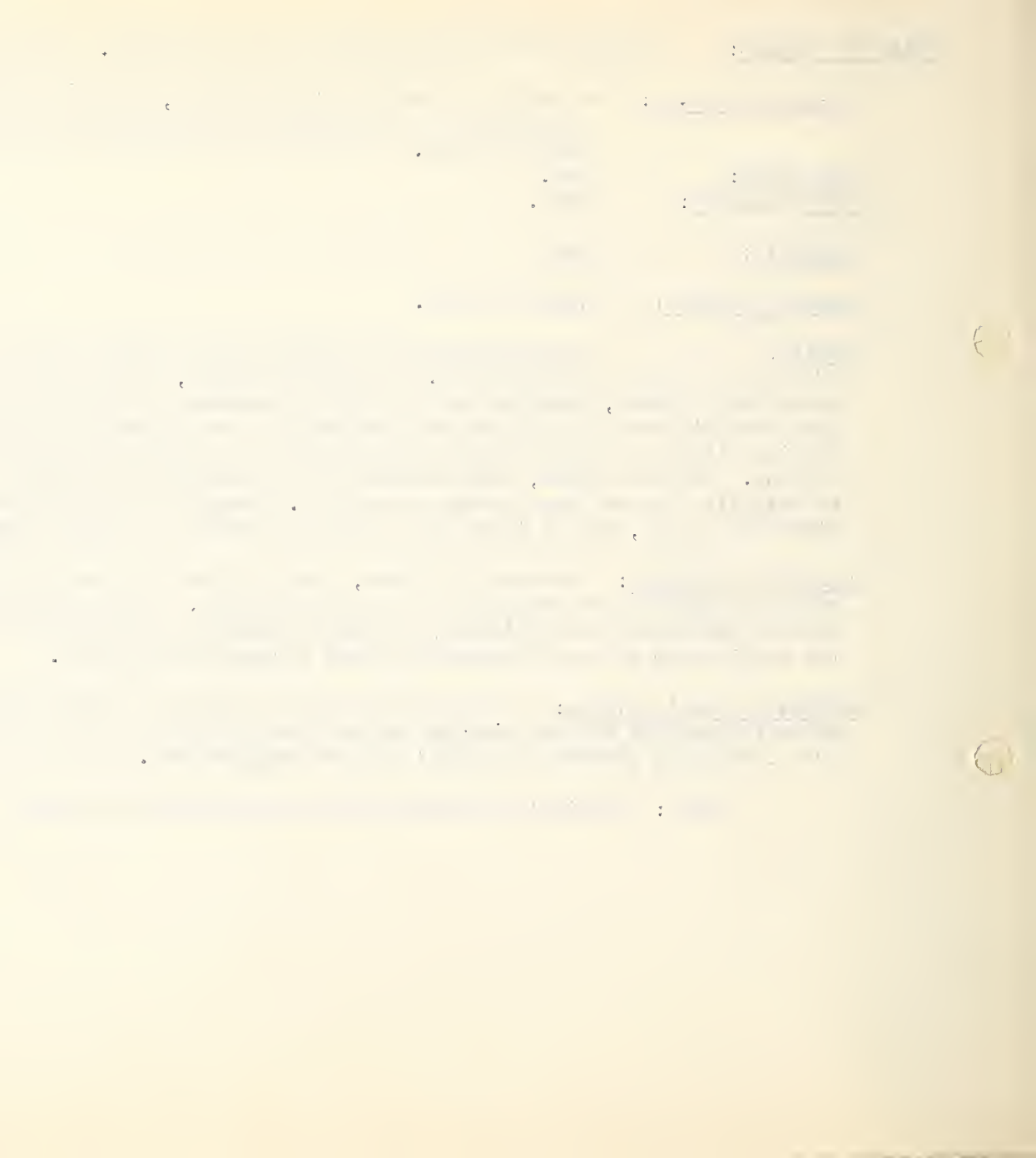
Cost of the work: \$2,500 per year.

Results: The effectiveness of cold storage depends very largely upon the maintenance of suitable storage temperatures. It has been found, through the investigations carried on under this project, that the position and arrangement of the cooling pipes have a marked effect upon the uniformity with which temperatures can be maintained in different parts of the room. Cooling pipes are most effective and provide most uniform temperatures when placed on the ceiling. The same pipes, when mounted on a side wall of the room are less effective and fail to maintain uniform temperatures throughout. Temperature conditions in storage rooms having side wall piping, may be improved by the application of suitable board baffles or partitions.

Economic importance: Losses in storage, due to inadequate regulation of storage temperatures, amount to hundreds of thousands of dollars annually. A considerable percentage of this loss can be avoided and the efficiency of many existing storage houses materially increased, through the application of the information gained through this project.

Estimated annual savings: Information gained through this project makes possible the more effective control of cold storage temperatures and the reduction of losses in storage resulting from inadequate methods of control of such temperatures.

Note: No similar investigations are carried on by State experiment stations.



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BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF MECHANICAL EQUIPMENT

Title of project: Mechanical Control of European Corn Borer.
Date begun: July 1, 1927
Date completed: In progress.

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering **** "for investigations, experiments and demonstrations involving the application of engineering principles to agriculture **** upon farm power and mechanical farm equipment."

Cost of work: Has varied. Fiscal year 1933 - \$63,200.

Results: Because of the critical studies made in cornstalk debris coverage and the performance characteristics of some sixty plows, the manufacturers are improving the design of their plows according to many of the recommendations made by the Bureau engineers. These include greater clearance for easier passage of trash, larger colters, and better arrangements of parts to minimize the lodging of stalks. These improvements make good clean plowing possible at no increased cost over present practices. Thereby many weed and insect pests, as well as the corn borer, may be controlled at the same time the seed bed is being prepared.

Another result from this work is the development of a low-cost trash guide plow attachment which enables a farmer with reasonable care to effect an almost complete job of stalk covering with his plow. Covering wires under most conditions proved to be fairly effective for holding the stalks as the furrowslice turned over and covered them. The trash guides supersede these and act as a guide or funnel for guiding the stalks to the bottom of the furrow just before the furrow slice covers them over. Many pretreatments were tried out with a view of enabling the plow to effect better coverage. These included chopping of the standing stalks with a stalk chopper, rolling, discing, dragging, etc.

Investigations on the application of insecticides indicate that they can be best applied by mounting spray nozzles at a fixed position with relation to the young cornstalks. Previously, attempts had been made at mechanically turning the stalks so that all sides would be exposed to the spray.

Experimental work on methods of killing borers by heat resulted in the development of a low pressure, flexible hood, pulled type field burner. While this machine performed satisfactorily, it was found to have too high initial and operating costs when compared with other less costly equipment now developed or in the process of development. Although too expensive for corn borer control, the burner has proven to be effective in the control of the pea aphid in alfalfa, particularly in

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the Antelope Valley of California, and is also being found useful in apple orchards in Kansas. Promising results were obtained from one season's work with stem rot in rice stubble fields in Arkansas. The tests included studies of the application of steam, the tolerance of borers to moist and dry heat, and the testing of commercial burners.

Investigation of corn harvesting equipment resulted in the development of (1) a stationary knife, low-cutting attachment for the four commercial makes of corn binder on the market and low-cutting hand hoes for use in both the middle western and eastern areas infested with the corn borer. Both of the above developments permit the cutting of corn flush with the ground surface. These improvements did away with the need of the stubble pulverizer which would have been a considerable burden to the farmer in first cost and in cost of operation. (2) A two-row stalk shaver for cutting stalks, from which the corn has been picked, flush with the ground. (3) A four-bar side delivery rake from commercial three bar rakes for cleanly raking stalks into windrows for burning or other disposal after they had been severed by the stalk shaver.

Several ideas were tried out for mechanically killing borers in fields of standing stalks. These included the stalk piercing machine and the stalk beater. An idea was also worked out for slitting the stubble left as the ordinary binder harvested the corn.

Tests were also made on the adjustments and operating characteristics of ensilage cutters and husker shredders to determine operating condition necessary to produce a high mortality of borers contained in corn fodder. Tests on baling pressures necessary for a high kill were likewise made.

A stalk chopping attachment is being developed for use on a mechanical picker, thereby permitting the destruction of the borers in the stalks as the corn is being picked.

Low-cutting sled harvesters are also in the process of development for use where it is not practical to use a low-cutting hoe nor economical to use a corn binder.

Economic Importance: The European Corn Borer because of its destructive habits is a menace to the two-billion dollar corn crop of the United States. In Essex and Kent counties in Canada, where corn growing practices are similar to those in the corn belt, the borer destroyed in 1925, the entire corn crop area of 400 square miles and was responsible for practically the total loss of the corn crop covering an area of 1200 square miles. Thus far the use of farm machinery has proven the only effective and practical method of controlling the borer.

An area of approximately 250,000 square miles is infested in the United States and the natural spread continues toward the corn belt at the rate of about twenty five miles per year.

Apparently only unfavorable weather conditions the past three years have prevented serious commercial damage.

Because of the potential damage of the pest the machinery investigation should be continued so that adequate control measures will be available when the need becomes urgent.

Plowing is the most expensive operation on the farm. By doing a good job of plowing as compared with a poor job, the work involved in seed preparation is lessened. To effect a good job, the plow must be in proper adjustment, which reduces draft and consequently the cost of the operation. Weeds are more easily controlled, as well as many insect pests. Clean plowing is a very effective measure in the control of the corn borer.

In 1930 there were approximately 100 million acres in corn. Of this acreage probably 10 per cent is cut with a binder, 40 per cent sown to small grain, and 10 per cent picked with the mechanical picker. With the use of the low-cutting corn binder, corn can be harvested at the same cost as with the regular binder, the only additional expense being about \$10 for the attachment.

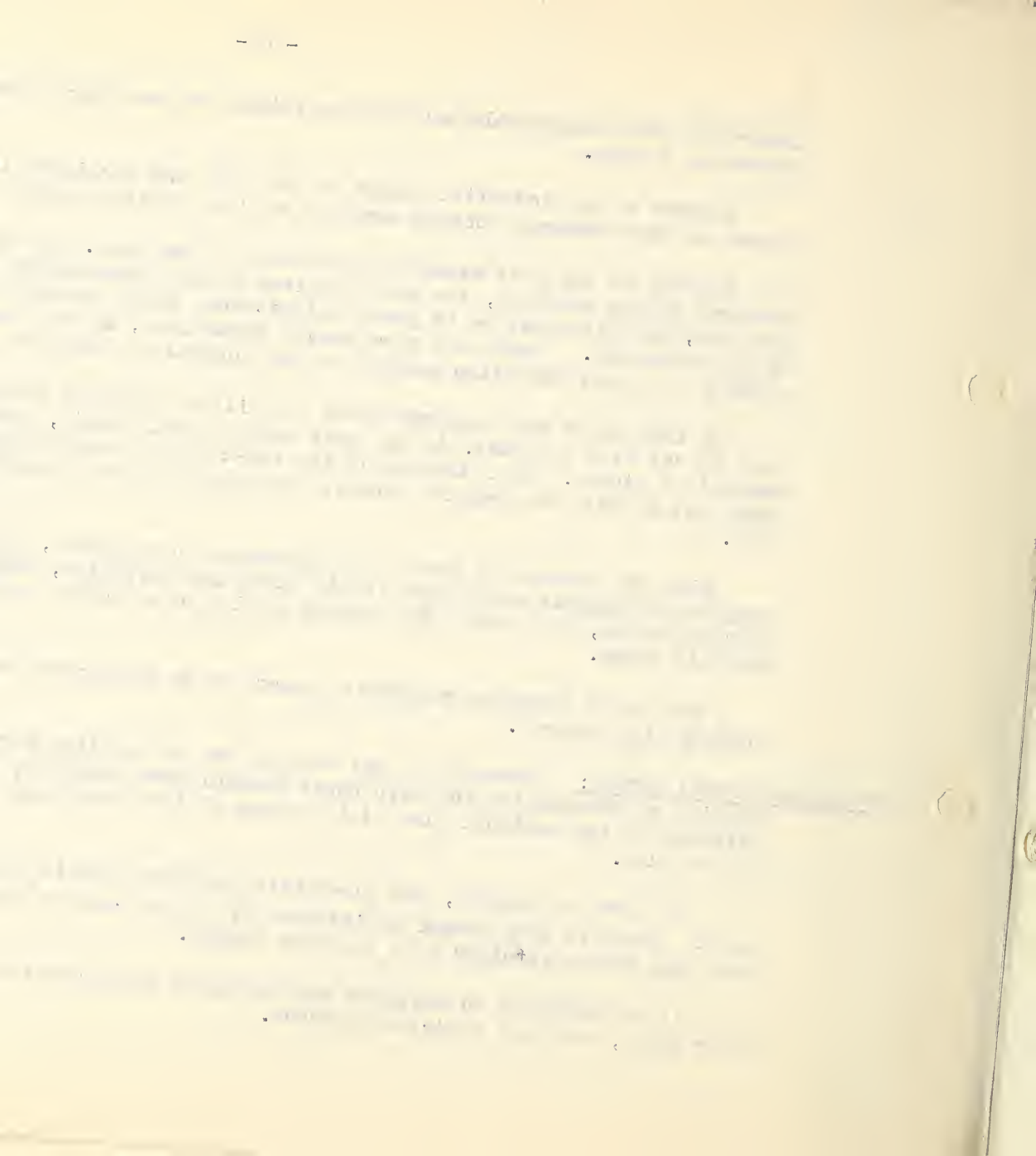
With the increasing use of the mechanical corn picker, the use of a satisfactory stalk chopping attachment would cost little extra for operation, would control the borer in a once-over operation, and permit the chopped stalks to be thrown back on the land to aid in maintaining the soil humus.

The use of spraying equipment appears to be applicable only in fields of sweet corn which produce high returns.

Estimated Annual Saving: Probably 40 per cent of the 100 million corn acreage is plowed each year. If plowing as recommended for corn borer control were generally used, a huge saving would be effected in the national plow bill because of less draft and consequent less power requirement of the plow.

In times of drought, the low-cutting equipment would increase the ensilage tonnage per acre. Tests in 1929 showed an increase of 16 per cent in fodder which was cut low as compared with the fodder obtained by a standard binder.

It is difficult to estimate the saving by the operation of shaving, raking and burning over other, but less efficient methods.



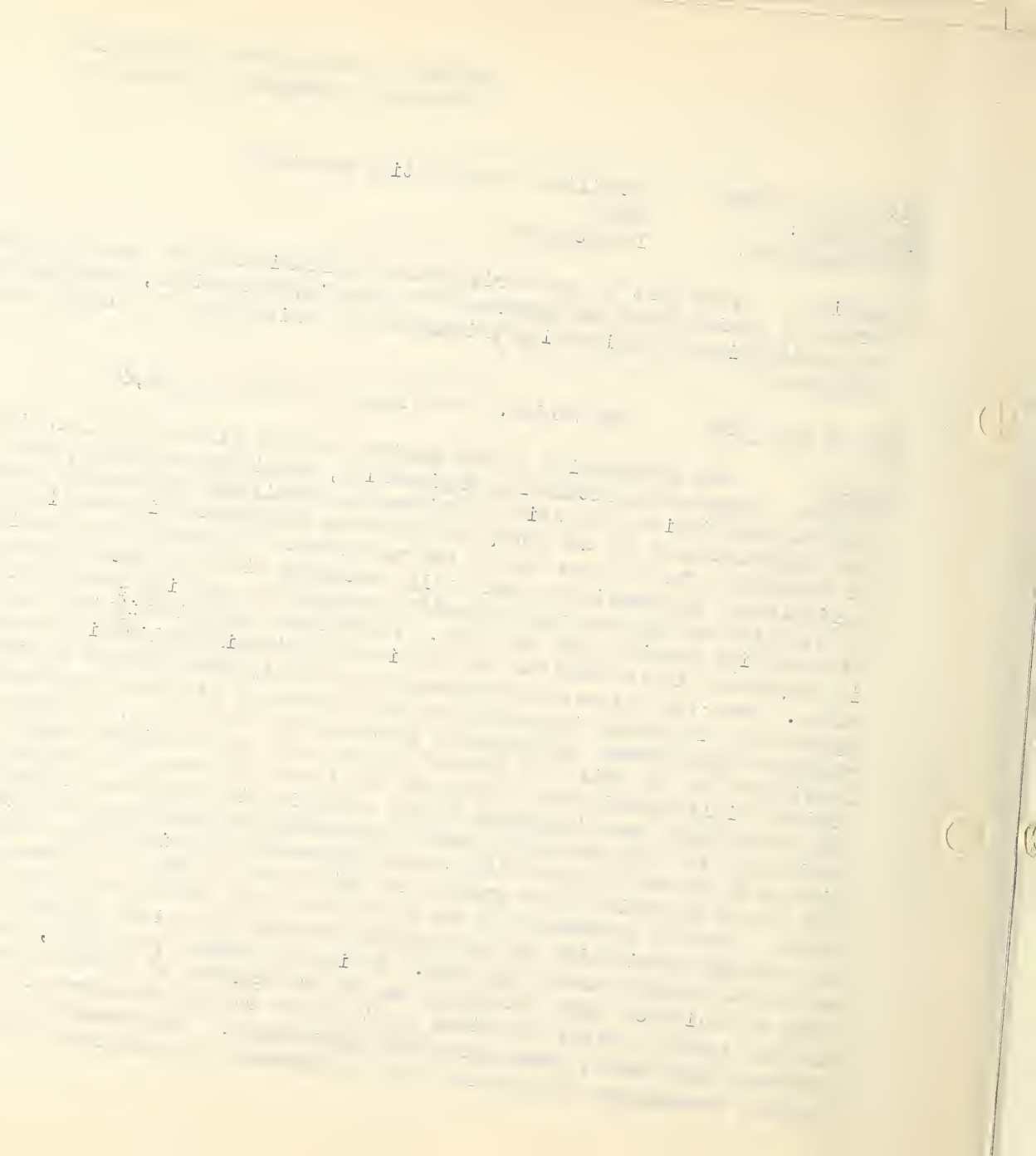
BUREAU OF AGRICULTURAL ENGINEERING
Division of Mechanical Equipment

Title of project: Fertilizer Distributing Machinery
Date begun: 1924
Date completed: In progress

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering **** "for investigations, experiments and demonstrations involving the application of engineering principles to agriculture **** upon farm power and mechanical farm equipment."

Cost of the work: Has varied. For fiscal year 1933 - \$19,600

Results: The cooperation on the project for the fiscal year 1933 includes the following agencies: Federal Bureaus of Agricultural Engineering, Chemistry and Soils, and Plant Industry, The National Fertilizer Association, the Joint Committee on Fertilizer Application, and experiment stations in 14 States. The general object of the study is to secure fundamental information on the properties and application of commercial fertilizers and on the performance of fertilizer distributing machines. The Bureau of Agricultural Engineering is primarily concerned with the characteristic performance of different types of distributors and the most effective methods of applying fertilizers on which improved designs of distributing machines can be based. Fertilizers are distributed irregularly by present machines and in many cases it is difficult to obtain and maintain application rates reasonably close to those desired. Most fertilizers become damp very readily when exposed to humid air and under these conditions application is either impossible or unsatisfactory with most machines. A study of the fertilizer placement attachments on planters, particularly for cotton, has shown that the final position of the fertilizer in the soil with respect to the seed varies widely among different makes of machines. Controlled field experiments to date on fertilizer placement for cotton, potatoes, beans, sweet corn, and sugar beets have indicated a wide variation in fertilizer injury to germination and fertilizer efficiency in crop production among representative placements of fertilizer. Fertilizer placements similar to those obtained with certain commercial machines have resulted under average conditions in few plants appearing above ground, in which case it would have been necessary for the farmer to re-plant. Certain placements of the fertilizer, for example in a band at each side of the seed, have not delayed germination and have rather consistently given higher yields than other placements such as a band directly under the seed. During the fiscal year 1933, studies will be made in the laboratory at Arlington Farm, Virginia, on the performance of different types of fertilizer distributors and in the field at thirty locations in 17 States on the placement of fertilizer for cotton, potatoes, tobacco, snap beans, sweet corn, and sugar beets. Improvements of distributing machines based on further fundamental information will be necessary for accurate distribution of fertilizer and for



Title of project: Fertilizer Distributing Machinery (Cont).

proper placement with respect to the seed or plant, which will avoid injurious effects and insure the largest possible increases in yield.

Economic importance: Commercial fertilizers under present farming practices are essential to the economic production of crops on many soils and in some localities crops cannot be produced without their use. In 1929, the Department of Agriculture estimated that fertilizers as then applied were only 50 per cent efficient. According to the National Fertilizer Association, the principal fertilizer consuming States used 6,694,000 tons of fertilizer in 1927 at a total cost of \$213,233,000, and the value of the crops produced by the fertilizer was \$754,343,000. According to available estimates, 8,109,636 tons of fertilizer were consumed in the United States during the year 1930.

Estimated annual saving: This Bureau is concerned only with the mechanical phases of the problem and the study has not yet progressed to the point where definite conclusions can be drawn. The indications are that efficiency of fertilizers might be increased 10 per cent by accurate and proper machine application. As based on the figures above mentioned for 1927, a fertilizer efficiency of 60 per cent instead of 50 per cent would result in an increase of \$150,868,000 in the value of crops produced by commercial fertilizer.

BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF MECHANICAL EQUIPMENT

Title of project: Sugar beet production machinery
Date begun: 1928
Date completed: In progress

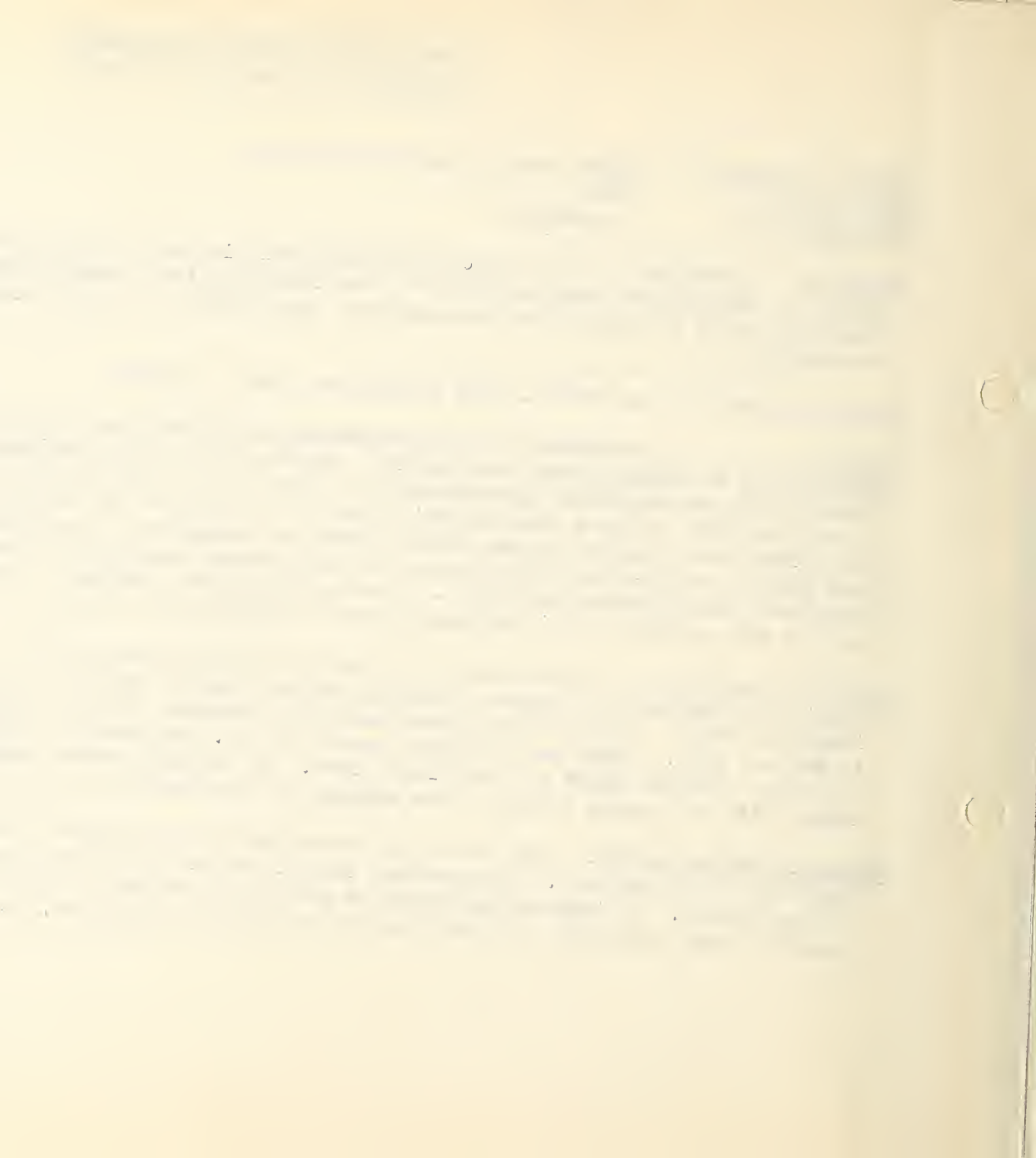
Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering **** "for investigations, experiments and demonstrations involving the application of engineering principles to agriculture ***** upon farm power and mechanical farm equipment."

Cost of the work: Has varied. For fiscal year 1933 - \$14,200

Results: Development of a satisfactory mechanical cross blocker by proper selection of shovels and spacing on standard beet cultivators. Studies of existing equipment led to the development of the above, which was tried out satisfactorily in the field in California and Colorado two years. A fertilizer attachment, using a metering unit similar to that used in the fertilizer studies on other crops, was worked out. Results of one season's work are promising. Analytical studies of beet harvesters have pointed out to the manufacturers the requirements necessary to perform satisfactorily under both California and Colorado conditions. Studies of planters indicate a possible more economical use of seed as well as the possible elimination of blocking due to planting in hills.

Economic importance: A large amount of hand labor, mostly imported, is used in chopping, thinning, and topping, harvesting and loading, probably proportionately more than is used in the growing of other important crops. In 1930, hand labor costs for thinning, hoeing, and topping alone ranged from \$23 to \$26 per acre. Labor and machinery costs were 68.5 per cent of total production costs, or \$58.86 per acre, with man labor as the largest item. By the development and use of suitable equipment, the importation of foreign labor for the purpose can undoubtedly be greatly reduced.

Estimated annual saving: The use of the cross blocker has reduced the hand labor requirement of that operation by 30 per cent. The straight cross rows left permit of easier weed control, and thinning is facilitated. An improved harvester as well as seeder will effect a still further saving with a possible total reduction of 50 per cent in the cost of producing, harvesting, and loading the crop.



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BUREAU OF AGRICULTURAL ENGINEERING
Division of Mechanical Equipment

Title of project: Cotton Production Machinery
Date begun: 1931
Date completed: In progress

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering "**** for investigations, experiments and demonstrations involving the application of engineering principles to agriculture **** upon farm power and mechanical farm equipment."

Cost of work: Has varied. Fiscal year 1933 - \$16,300.

Results: In cotton planting investigations it was found that the depth at which the seed were planted and weather conditions have a great influence on the stand of cotton obtained. Shallow planting gave best results during wet seasons and deep planting during dry seasons. The weather, however, could not be predicted far in advance. In an effort to assure a stand regardless of weather conditions, a variable depth cotton planter was developed by Bureau engineers and a public patent obtained. This variable depth planter, which is in reality an attachment for planters now in common use, plants the seed in a vertical sine curve underneath the surface of the ground. If wet weather follows, the seed nearest the surface of the ground come up and if dry weather prevails the seed planted some distance from the surface come up, thus assuring a stand of cotton regardless of weather conditions. The results of tests made over a period of two years show that a better stand of cotton was obtained with the variable depth planter than with other planters. Farm machinery manufacturers are, or are considering placing on the market a planter incorporating the variable depth idea.

Tests in which plots of cotton receive no cultivation at all, and other plots receiving various amounts including some in which more cultivating was done than is customary under farm conditions, showed that cultivation beyond that required to kill weeds is unnecessary.

Draft tests made on plows and cultivators indicate that power requirements can be reduced by changes in design and plows embodying these improvements have been designed.

(1)

(2)

The practice of snapping, stripping, and sledding cotton in northwest Texas made it possible in that area for farmers to select a method of harvesting best suited to weather conditions, price of cotton, and availability of labor at harvest time. As a result of these developments in northwest Texas, efforts were made to develop similar methods in the Mississippi Delta. It was found, however, that due to the rank growth of cotton plants in the Delta region these new methods of harvesting would not be practicable. The reduction in market value due to the large amount of leaf and trash in the cotton more than offset any saving resulting from a reduction in the cost of labor.

Economic importance: The cotton crop is one of the major crops grown in the United States. It has been estimated that 400,000,000 horsepower-hours of energy is expended annually in preparing the land, and in planting and cultivating the crop. The item of chopping and hoeing the crop has been estimated to cost about \$96,000,000 per year with labor at 12 cents per hour. With labor at the same price the cost of picking approximates \$156,000,000. With these figures in mind, it is evident that any improvements which can be made in the methods or mechanical means used in producing and harvesting the crop will be of vast economic importance. It is believed that at least 10 per cent of the cotton crop is replanted annually and if any considerable portion of this replanting can be obviated by means of the variable depth cotton planter, this one development is of great importance.

Estimated annual saving: The variable-depth planter developed by the Bureau is not as yet in use on enough farms to justify an estimate as to the saving in the cost of planting cotton. The findings with reference to tillage operations have, of course, been applied in few cases as yet and no definite statement can be made as to the possible savings involved.

This project is being carried on in cooperation with various State Agricultural Experiment Stations.

BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF MECHANICAL EQUIPMENT

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Title of project: Sugar cane harvesting machinery
Date begun: April 1, 1931
Date completed: Stopped July, 1931 on account of the death of the engineer in charge and inability to replace him.

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering **** "for investigations, experiments and demonstrations involving the application of engineering principles to agriculture **** upon farm power and mechanical farm equipment."

Cost of the work: \$2,000

Results: A resume' of literature reviewed, and a compilation of pertinent information dealing with sugar cane production machinery, including tillage machinery, planters, cutters and toppers, and harvesters.

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BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF MECHANICAL EQUIPMENT

Title of project: Corn production machinery
Date begun: 1931
Date completed: In progress

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering **** "for investigations, experiments and demonstrations involving the application of engineering principles to agriculture **** upon farm power and mechanical farm equipment."

Cost of the work: Has varied. For fiscal year 1933 - \$14,700

Results: Data derived from critical performance studies of a number of different makes of mechanical corn pickers have been responsible for a number of improvements by their respective manufacturers.

Other corn picker tests indicated that three men with a mechanical picker could harvest, transport, and crib corn at the rate of about 100 bushels per hour. It would require twelve to fifteen ordinary men picking by hand to harvest and crib at the same rate.

A unique wagon hitch for unhitching and hitching a wagon to the tractor alongside the picker, from the tractor operator's seat, has been devised.

A tractor dynamometer for measuring power input to machines has been developed which permits of simultaneously or separately securing the amount of power delivered by the engine to the tractor wheels, power take-off, and drawbar.

Results of one year's studies on the comparison of three methods of planting and cultivating corn indicated that the labor requirements for preparing the seed bed, planting and cultivating were: check planted corn, 4.0; drill planted corn, 3.6; and listed corn 2.6 man hours per acre. Weed control results were about the same in the three methods. There was no significant difference in yield between drill planted and listed corn although drilled corn showed a 5-bushel increase over that of check planted corn.

Economic importance: Labor requirements for producing and harvesting corn vary from 5 to 300 man hours per acre. By making use of a suitable combination of machines and methods, the lower figure may be approached.

Title of project: Corn production machinery (Contd).

Hand picking of corn is a very arduous operation and will rapidly be replaced by the mechanical corn picker as the performance of that machine becomes improved.

Estimated annual saving: The value of the corn crop in 1932 was approximately $1\frac{1}{2}$ billion dollars.

While this project has not been in progress long enough to estimate savings, if the proper methods were generally used the reduction in labor requirements herein indicated would effect an appreciable percentage of the above figure as a saving in producing the crop.

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BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF MECHANICAL EQUIPMENT

Title of project: Utilization and cost of farm power and machinery
Date begun: 1927
Date completed: 1933

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering *****for investigations, experiments and demonstrations involving the application of engineering principles to agriculture ***** upon farm power and mechanical farm equipment."

Sub-project no. 1: Use of power and machinery in Pennsylvania
Date begun: 1927
Date completed: 1928

Authority: That part of the appropriation act, Bureau of Public Roads, as follows: "for investigating ***** other rural engineering problems involving mechanical principles.

Cost of the work: \$1,000

Results: Records were obtained in cooperation with the Pennsylvania Agricultural Experiment Station in ten counties in Pennsylvania showing the type of agricultural machinery used, the size of machines and power units, the years of service rendered by the machine, and the cost of using various machines. The following is in part a summary of the survey:

Tractors were found on from 13 to 48 per cent of the farms where records were taken at random.

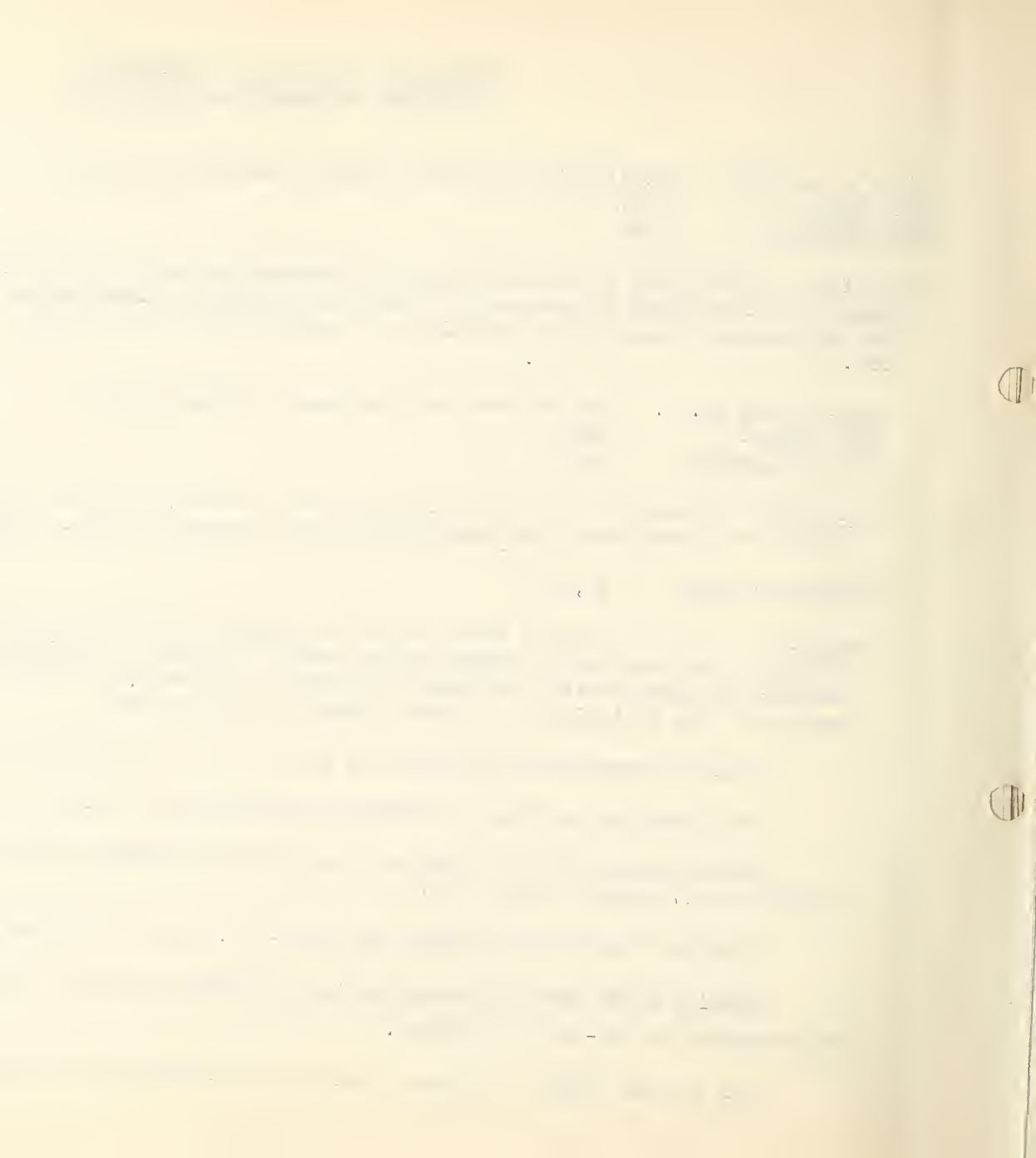
The length of service of tractors was estimated at 10.5 years.

Annual repair costs on tractors during 1926 averaged about \$18. The machines had been used an average of 4.7 years at that time.

Tractors were used 36.6 days per year - 23.9 days for drawbar work and 12.7 days for belt work.

Walking plows were in common use in all sections studied, riding plows were rarely found, with the exception of two-way sulky plows.

The one-way riding cultivator, used with two horses, was practically universal through the state.



Title of project: Utilization and cost of farm power and machinery

Sub-project no. 1: Use of power and machinery in Pennsylvania (continued)

The years of service rendered by machines did not vary greatly with the amount of use.
The data derived from this project are valuable not only in Pennsylvania but wherever farm machinery and power is used under similar conditions.

Estimated annual savings: No data are available as to the amount of annual savings.

Sub-project no. 2: Utilization and cost of farm power

Date begun: 1929

Date completed: 1933

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering **** "for investigations, experiments and demonstrations involving the application of engineering principles to agriculture **** upon farm power and mechanical farm equipment."

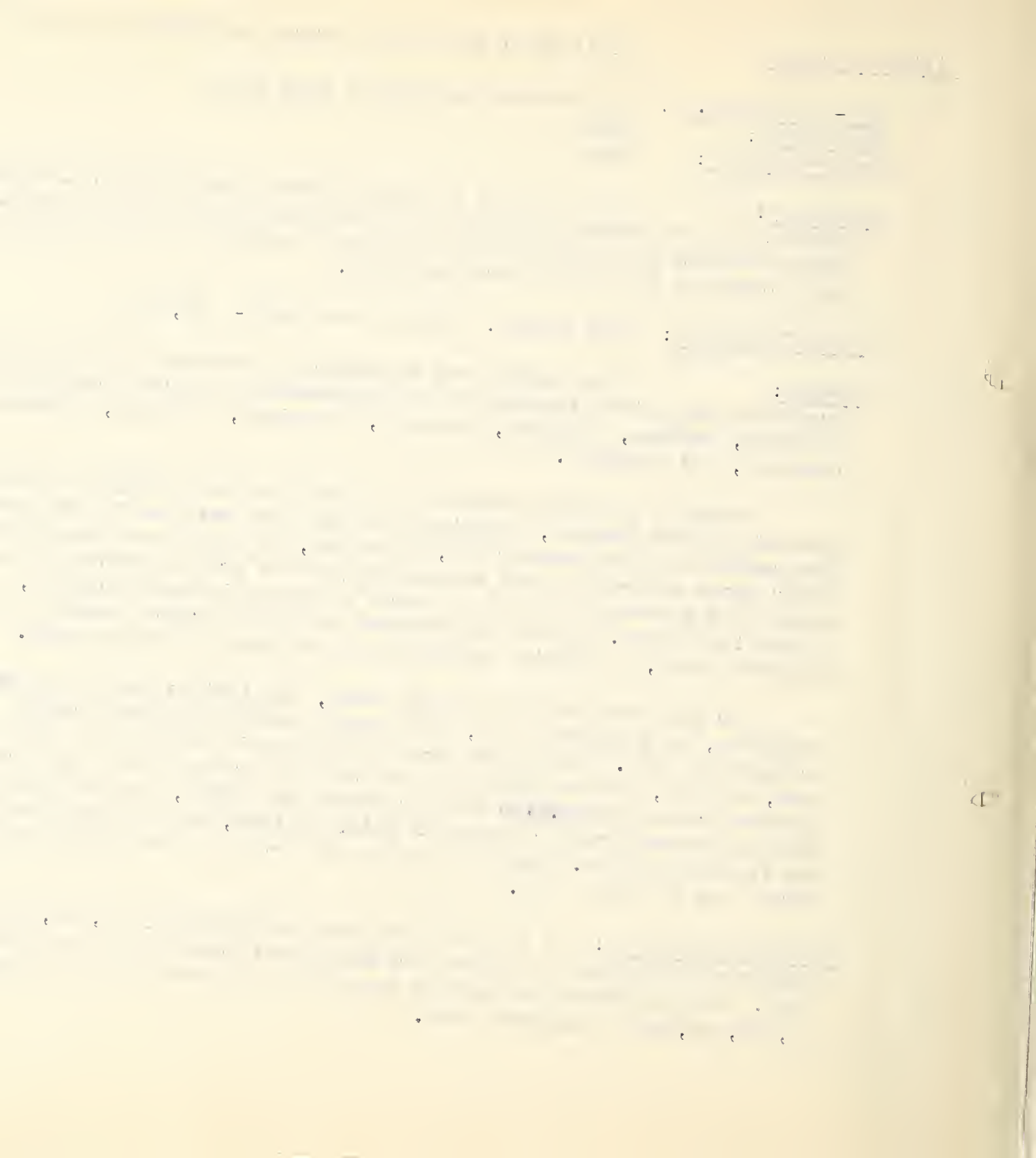
Cost of the work: Has varied. Fiscal year 1933 - \$3,100

Results: The project was conducted in cooperation with the Bureaus of Agricultural Economics and Animal Industry of the Department of Agriculture and the Experiment Stations of Illinois, Indiana, Michigan, Missouri, Louisiana, Arkansas, Mississippi, Georgia, South Carolina, and Virginia.

Probably the most outstanding finding of the survey was the widespread use of the general purpose tractor, especially in the corn belt and in the Yazoo Delta region of Mississippi. The general purpose tractor can, of course, be used for a greater number of operations than other types of tractors and consequently for a greater number of hours each season. By increasing the number of hours in which a tractor is used annually, the overhead cost per hour of use is reduced. Since the overhead cost of a tractor makes up a large part of the total operating cost, a material saving can be effected in this manner.

In the corn belt and in the Yazoo, Mississippi Delta the per acre cost of producing crops was, as a general rule, less when a general purpose tractor was used than with horses or mules in 1930. Due to the great reduction in the cost of feed and man labor since that time, however, the per acre cost in 1932 was probably less on horse farms than on general purpose tractor farms. In the production of cotton, the per acre cost was less with the general purpose tractor than with mules in 1930, but the cost per pound of cotton produced was less with mules. This was due to the fact that the yield per acre was less on tractor farms than on mule farms.

Economic importance: It is estimated that approximately 17,000,000 horsepower hours of energy was developed by animal and mechanical power units on farms in the United States in 1930. On this basis the cost of power to the farmers of the United States approximated \$1,190,000,000 during that year.



Title of project: Utilization and cost of farm power and machinery (continued)

Sub-project no. 3: Power and machinery in agriculture

Date begun: 1929

Date completed: 1933

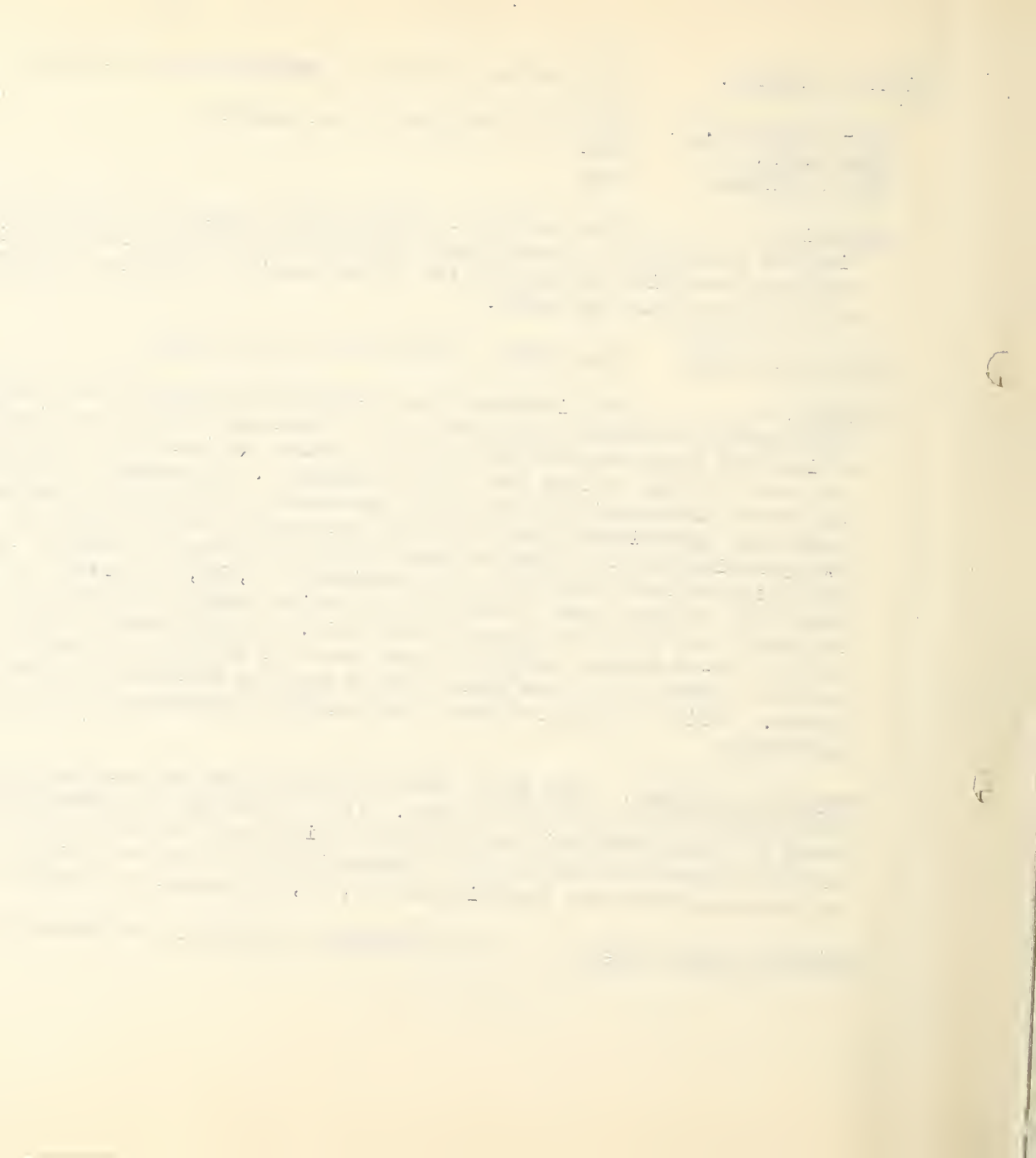
Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering **** "for investigations, experiments and demonstrations involving the application of engineering principles to agriculture **** upon farm power and mechanical farm equipment."

Cost of the work: Has varied. Fiscal year 1933 - \$3,000

Results: The increased use of power and machinery has resulted in a reduction in labor requirement per unit of crop production, a decrease in the total number of agricultural workers, an increase in acreage per agricultural worker, an increase in value of farm power units and machinery, and a change in feed and fuel requirements. The number of animal power units decreased and the number of mechanical power units increased on farms in the United States between 1918 and 1930. There were approximately twice as many automobiles, between six and seven times as many trucks, and approximately four times as many tractors on farms in 1930 as in 1920. The horse and mule population on farms decreased by approximately 6,314,000 during the same period. The study also shows that tractor power is cheaper than animal power provided the power requirements are such as to justify the use of so large a power unit. At 1930 price levels of feed, labor, fuel, and lubricants, a 10-20 general purpose tractor could be operated at about the same total cost as four horses. By 1932, however, the same sized tractor could be operated at about the same total cost as six horses. During this period there was a greater reduction in the cost of feed than in fuel and lubricants.

Economic importance: The total value of power units and machinery on farms in the United States approximated \$4,650,302,000 in 1930. It is estimated that approximately 17,000,000,000 horsepower hours of energy were utilized on farms during that year and that 50 per cent of this power was furnished by mechanical power units. Mechanical power units consumed at least 2,000,000,000 gallons of petroleum fuels and approximately 92,000,000 gallons of lubricating oil in 1930.

Estimated annual saving: It is impossible to estimate any annual savings for this project.



BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF MECHANICAL EQUIPMENT

Title of project: Machinery for controlling insect pests
Date begun: 1917
Date completed: In progress

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering ****"for investigations, experiments and demonstrations involving the application of engineering principles to agriculture **** upon farm power and mechanical farm equipment."

Sub-project No. 1: Development of cotton dusting machinery
Date begun: 1917
Date completed: September, 1931

Authority: (Ibid).

Cost of the work: \$7,500

Results: Investigations of all promising types of dusting equipment for boll weevil control (including airplane, ground machines - both mule and tractor propelled - and hand machines) were carried to a point where the manufacturers of commercial equipment were in a position to carry forward the work in a satisfactory manner.

Economic importance: There are about 25 million acres subject to weevil damage each year. The use of efficient dusting machinery makes it possible to protect that portion of the cotton crop that justifies dusting.

Estimated annual saving: In normal times when the price of cotton would justify the expense of dusting, yields could be increased 200 to 400 pounds per acre. The past year, because of the comparatively high cost of dust, and a consequent lack of interest in dusting, a large amount of cotton was destroyed by the weevil. The annual saving might be estimated in normal times at 25 per cent of the then value of the cotton crop in the area concerned.

Title of project: Machinery for controlling insect pests

Sub-project No. 2: Southern field crop spraying and dusting investigations.

Date begun: October, 1931.

Date completed: In progress.

Authority: (Ibid).

Cost of the work: Fiscal year 1933 - \$6,000.

Results: Tests were made of typical spraying equipment used for spraying trees. The work is at present being done on pecan trees. Field observations and tests showed that the spray from different outfits varied considerably in the distribution and fineness of the particles. For the purpose of closer study, a focal plane shutter arrangement has been constructed which permits of the securing of the spray patterns from different nozzles. Because high pressures are becoming more popular, the effect of various pressures on the distribution and fineness of spray as hereby affected can thus be compared.

Economic importance: There are about 200,000 acres or nearly 3 million pecan trees - about one half of bearing age - in the Southern States. The average value of the pecan crop (1926-1930) was over eight million dollars. There are much larger areas of apples, peaches, and pears. If the fungus diseases which are becoming more virulent each year and the insect pests were allowed to continue undisturbed, the fruit and nut industry would soon be wiped out.

Estimated annual saving: The project has not progressed far enough to hazard an estimate as to the probable saving by spraying.

Title of project: Machinery for controlling insect pests.

Sub-project No. 3: Mechanical control of the pink bollworm of cotton.

Date begun: September, 1929.

Date completed: In progress of Texas.

Authority: (Ibid)

Cost of the work: Has varied. Fiscal year 1933 - \$5,000.

Results: In general, it was found that under conditions in western Texas the greatest control by cultural methods was secured by plowing followed immediately by irrigation. If irrigation were delayed until March when plots were plowed in January or February, larval survival was low, but if irrigation were delayed until April the survival increased considerably.

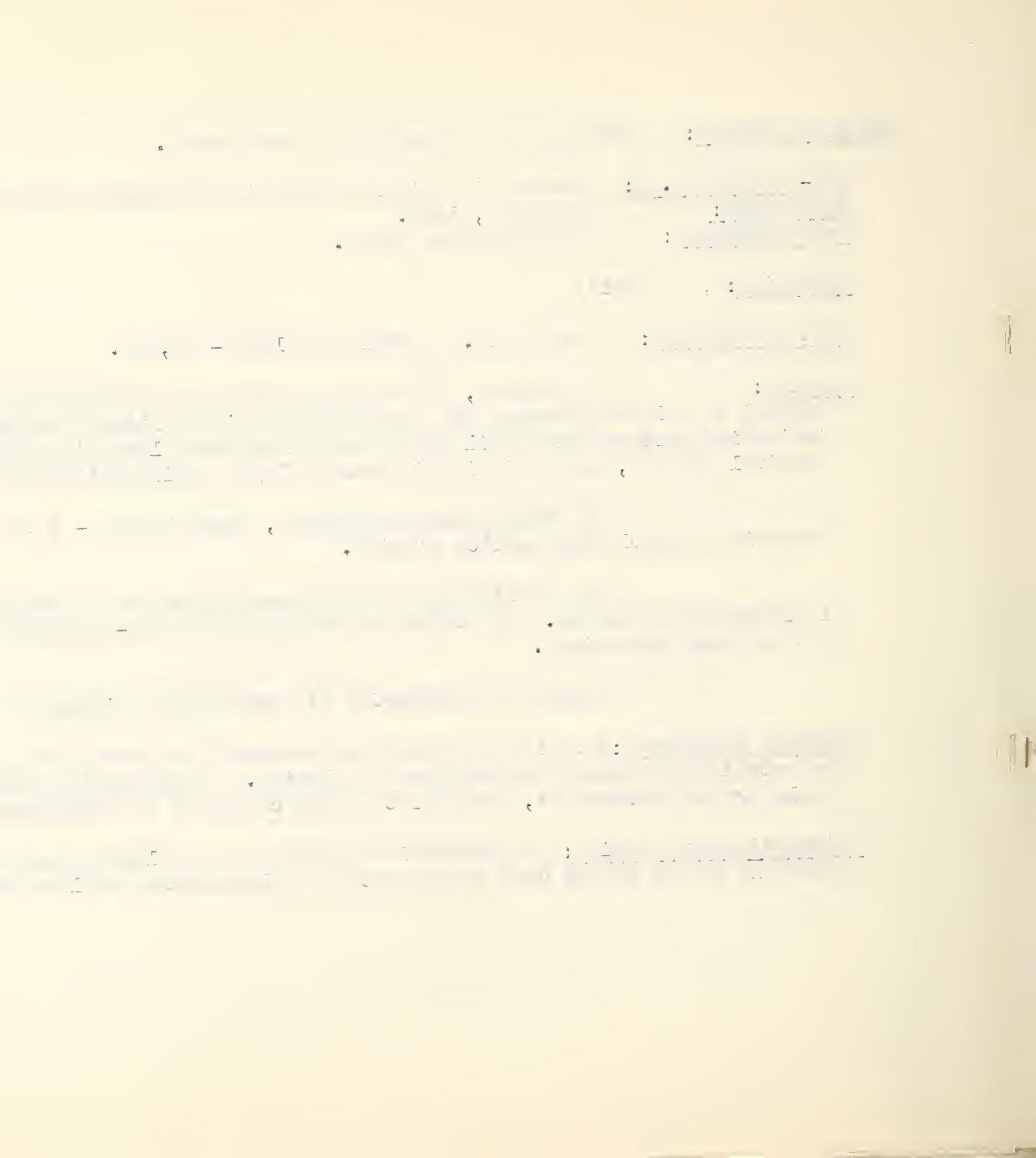
In hibernation experiments, deep plowing - 6 to 8 inches - was a more effective control than shallow plowing.

The application of soil insecticides as evidenced by one year's results indicates some promise. The effect of large scale clean-up measures used the past season has not yet been determined.

Methods of destroying gin trash under different conditions were worked out.

Economic importance: This insect appears to threaten the cotton crop of the United States. An infestation was found the past year in Florida. If repressive measures for use on a large scale are not worked out, the entire cotton crop will be jeopardized.

Estimated annual saving: If repressive measures are applied generally, probably one quarter to one half of the cotton crop in the present bollworm area will be saved to the farmer.



BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF MECHANICAL EQUIPMENT

Title of project: Artificial drying of crops.
Date begun: 1926
Date completed: In progress.

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering ---- "for investigations, experiments and demonstrations involving the application of engineering principles to agriculture ----- upon farm power and mechanical farm equipment."

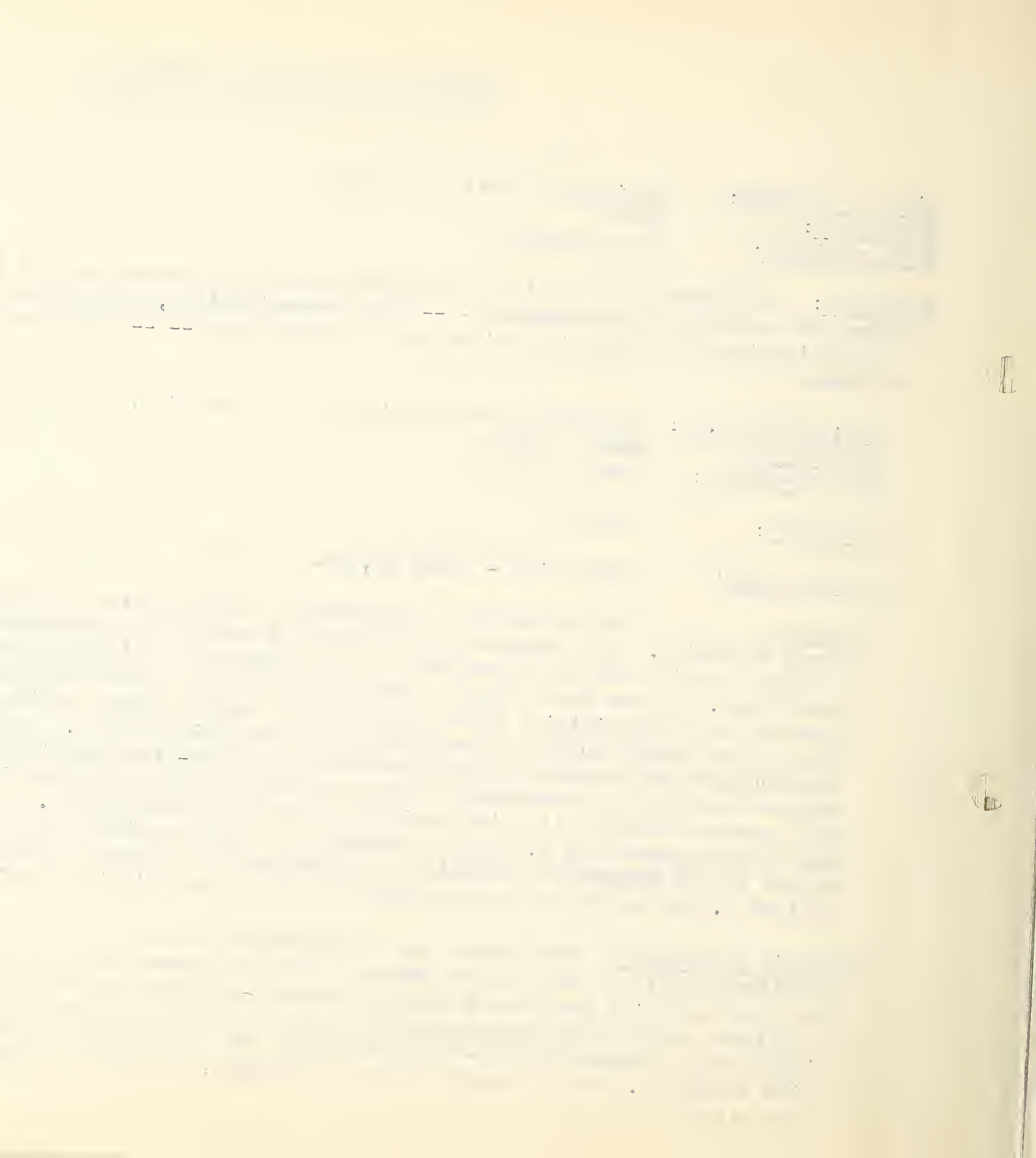
Subproject No. 1: Harvesting and artificial drying of rice.
Date begun: ~~1929~~ 1930.
Date completed: ~~1931~~ 1932.

Authority: (Ibid)

Cost of work: ~~Has varied - 1933, \$5,000.~~ Total cost of work, \$7,500.

Results: The project was a cooperative one involving this Bureau and the Bureau of Agricultural Economics. The Bureau of Agricultural Economics was concerned with the quality and condition (keeping quality and market value) of rice harvested by different methods and dried under artificial conditions. It was found that a high quality of rice can be obtained by using a combined harvester-thresher and an artificial drier but that the regular wheat combine is not entirely suitable for rice in the South because of wet fields and irrigation levees. Steps have been taken to encourage manufacturers to develop a machine suitable for rice-field conditions. In drying rice artificially, extreme care must be exercised in order to prevent injury to its milling quality. Rice kernels will crack or rupture if dried rapidly or at a high temperature. It was found that the drying air should not exceed 110° F. for best results if rice is dried in one operation. If rice is exposed to the drying process for a period of approximately 30 minutes each day until dry, a temperature of 120° F. may be used without material injury to the milling quality.

Economic importance: Rice driers are considered as necessary equipment by many rice millers, and practically all of the mills of modern design and recent construction have been installed. Driers are also essential when the combined harvester-thresher is used for harvesting rice. Manufacturers of driers have heretofore recommended that a drying air temperature of 150° F. be maintained. The difference in market value (1931 price level) of rice dried at 150° F. in one operation and rice dried at 120° F., with a short period of exposure, might be as much as 35 cents per barrel of rough rice.



Title of project: Artificial drying of crops (continued)

Subproject No. 1: Harvesting and artificial drying of rice (continued)

Estimated annual saving: So far as we know, no data are available as to the number of rice driers in the South or the number of bushels of rice dried annually. For these reasons it would be impossible to make an estimate as to the annual savings resulting from the work conducted by the Bureau, indicating the maximum drying air temperature for use on rice. However, at one plant the operator was able to double the capacity of the drier and reduce the operating cost of the drier by 50 per cent with no reduction in the milling quality of the rice, making use of the facts developed by this project. Similar work has not been conducted by any state experiment station.



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BUREAU OF AGRICULTURAL ENGINEERING
DIVISION OF MECHANICAL EQUIPMENT

Title of project: Artificial drying of crops (continued)

Subproject No. 2: Forage crop drying.

Date begun: 1926.

Date completed: In progress.

Authority: That part of the Agricultural Appropriation Act under an item in the appropriation for the Bureau of Agricultural Engineering ---- "for investigations, experiments and demonstrations involving the application of engineering principles to agriculture ---- upon farm power and mechanical farm equipment."

Cost of work: Has varied - 1933, \$4,120.

Results: The project is being conducted in cooperation with the Bureaus of Animal Industry and Plant Industry. The Pennsylvania and the Louisiana Agricultural Experiment Stations have similar projects on forage drying but neither is investigating all phases of the work; namely, engineering, agronomic, and physiological. The Bureau of Animal Industry is concerned with the nutrient value of the forage and the Bureau of Plant Industry is determining the proper stage of maturity of forage plants for the highest yield per acre, and the suitability of different varieties of forage crops in crop rotation where the drier is used. Work on the engineering aspects of the project so far has dealt primarily with a study of forage drying plants now in operation and installing machinery at the Iberia Livestock Farm, Jeanerette, Louisiana. A small apron conveyor and a revolving drum-type drier have been installed for experimental work at Jeanerette. A feeder, consisting of hot crushing rolls, will be tried out this season on the apron conveyor drier in an effort to increase the efficiency of this type of drier. Experiments have also been made with a combination field mower and crusher to determine the effect of crushing on the rate of drying in the field. Under favorable weather conditions crushed forage may dry out sufficiently in one day in the field to be baled or stored in a haymow. Tests are also being made as to the effect of the temperature and relative humidity on the moisture content of hay in storage.

Economic importance: In the more humid sections of the country, such as parts of the Gulf Coast States, probably at least 50 per cent of the hay crop is lost annually due to unfavorable weather conditions. A large variety of forage crops grow abundantly in these areas but it is difficult to obtain a high quality hay except during exceptionally dry seasons. With a drier available,

Title of project: Artificial drying of crops (continued)

Subproject No. 2: Dorage crop drying (continued)

the farmers in the South would be able to produce their own hay and forage crops and thus save the added expense of freight on such products shipped in from the North and West. The artificially dried hay graded "U. S. No. 1, Extra Leafy," is the highest possible grade. The indications are that the average grade of alfalfa hay on the market is U. S. No. 2. The average difference in price of U. S. No. 1 Extra Leafy alfalfa hay and U. S. No. 2 alfalfa hay in carlots on the Kansas City Market varied from approximately \$% to \$8 per ton from 1927 to 1931, inclusive. It is estimated that 25 per cent of the alfalfa crop in the Central States is seriously damaged annually by unfavorable weather at haying time. This loss in terms of market value is estimated as equivalent to an average of \$4 per ton (1927 to 1931 prices), which might be saved by artificial drying. In the more humid areas, such as in the Gulf Coast States, possibly an average of 50 per cent of the hay crop is lost annually due to unfavorable weather at harvest time.

Estimated annual saving: The artificial drying of forage crops is as yet in the experimental stage and until the practice becomes more general no definite estimate can be made as to the saving involved.

BUREAU OF AGRICULTURAL ENGINEERING
Cotton Ginning Investigations

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Title of project: Cotton Ginning Investigations.
Date begun: 1926.
Date Completed: In progress.

Authority: Public No. 160- 71st Congress, (U.S.C. Supp. V, title 7, Sec. 424, 425) and under item under Agricultural Department Appropriation Acts under Bureau of Public Roads and Bureau of Agricultural Engineering "****for investigations of cotton ginning."

Cost of work: Has varied. For 1933, \$48,630.

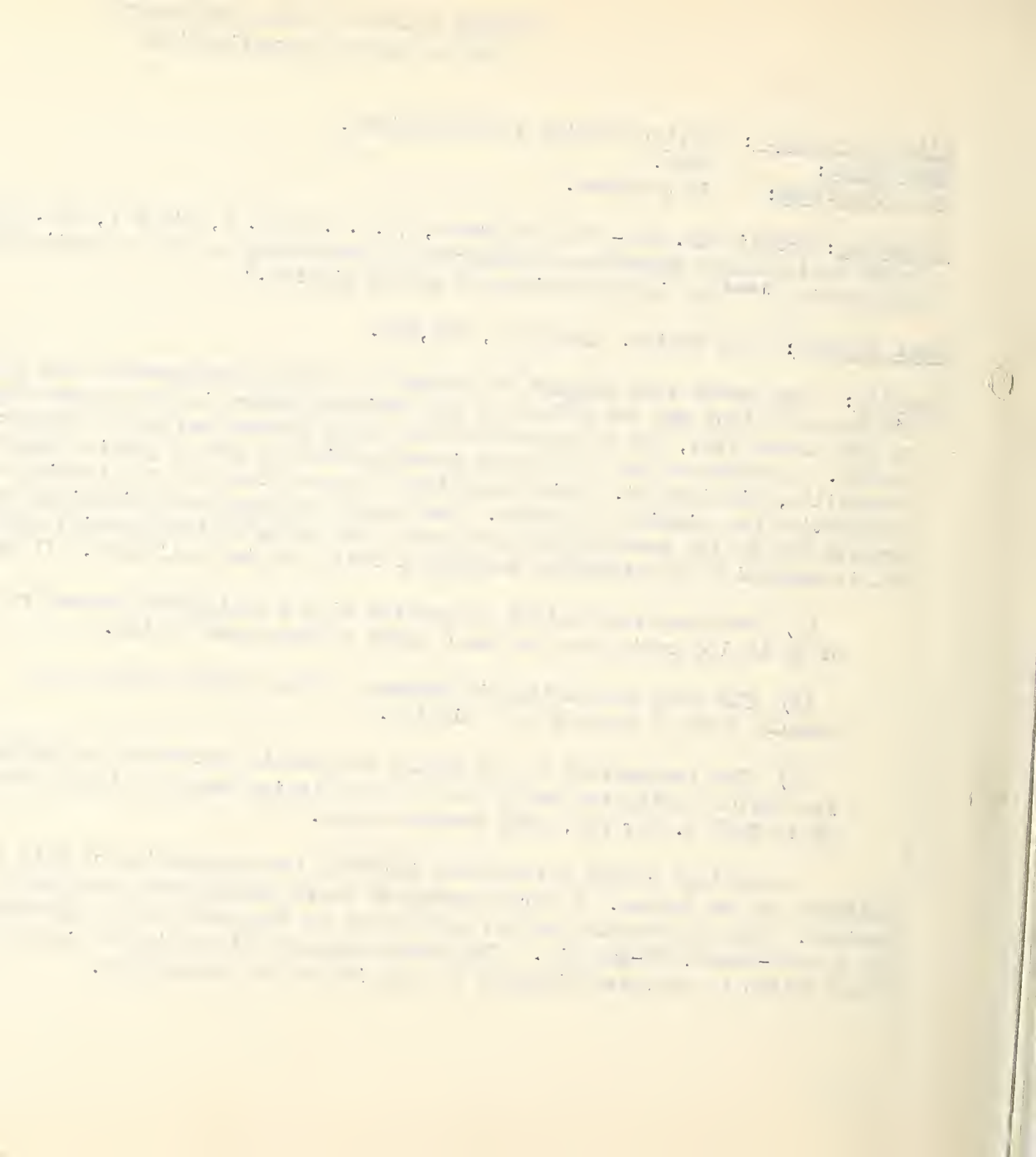
Results: Work under this project is planned to develop fundamental laws that govern the preparation and ginning of cotton and the effect of the various factors in the preparation and ginning of seed cotton on the ginned lint, and to devise ways by which present methods of preparation and ginning can be improved. In order to carry on these investigations a cotton ginning laboratory has been erected at Stoneville, Mississippi. This laboratory is now fitted for the testing of all equipment used in the preparation and ginning of cotton. One result of these investigations has been the development of a process for drying seed cotton which meets the predetermined special requirements for cotton drying and is adapted to all existing successful cotton drying equipment. It involves the following features:

(1) The damp seed cotton is treated with a continuous current of hot air at a rate of 40 to 100 cubic feet for each pound of damp seed cotton.

(2) The damp seed cotton is exposed to the drying process for a varying period, usually from 45 seconds to 3 minutes.

(3) The temperature of the drying air should preferably be between 160° and 200° F. for cotton during the early part of the ginning season but has been used satisfactorily up to 225° F. for wet, late season cotton.

A vertical cotton drier which involves the application of this process has been developed and patented by the Bureau. A large number of these driers have been built at commercial gins or on plantations. They can handle four or more bales of damp seed cotton per hour which is an amount sufficient for a four-stand, 80-saw gin. The driers operate satisfactorily in any kind of weather provided the dried cotton is conveyed directly to the gins in the heated air.

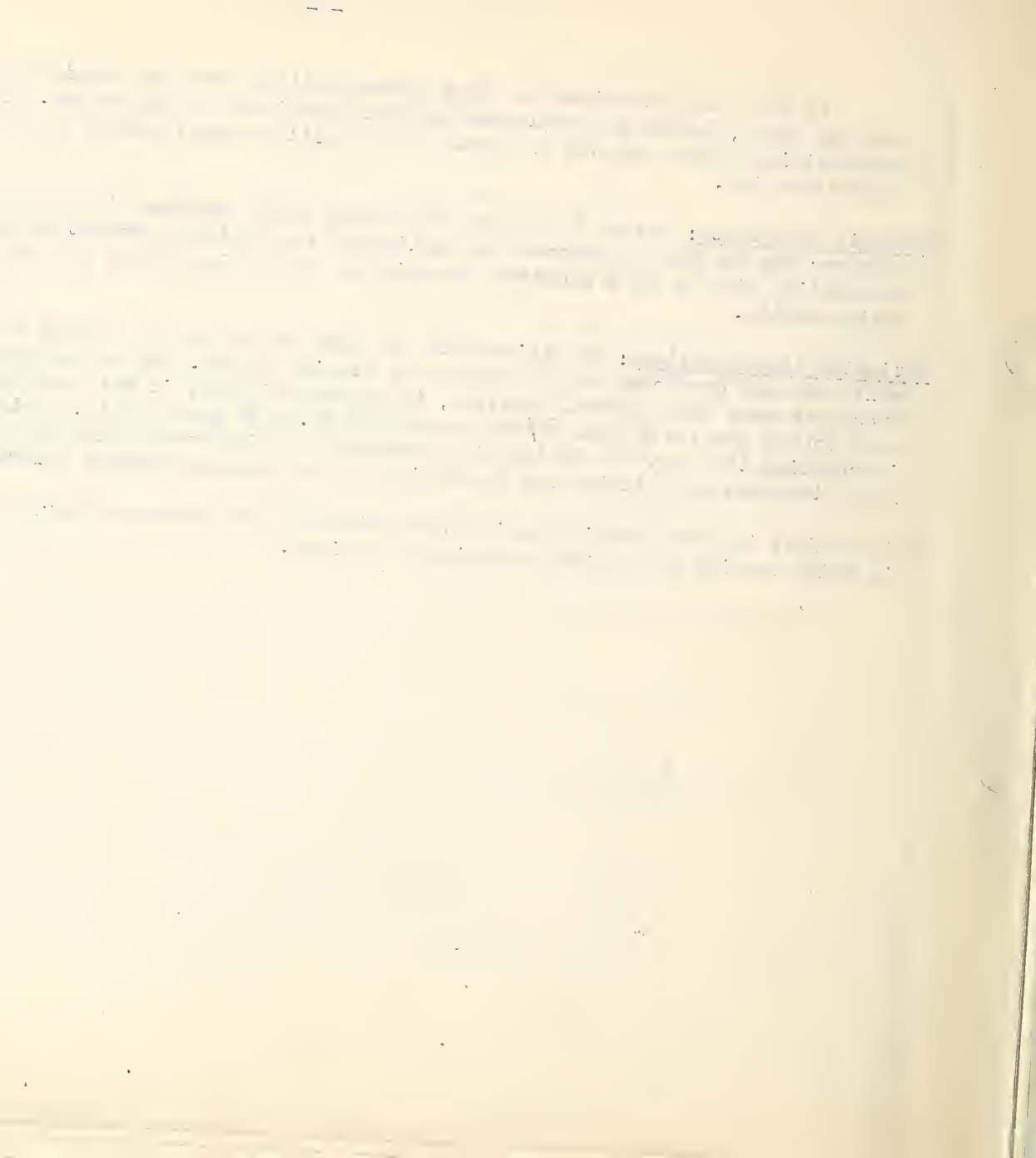


It has been determined by these investigations that the ginning of cotton has a very great effect upon the grade, length of staple and spinning qualities of the cotton. The investigation is now centered upon devising better methods of ginning which will conserve rather than destroy the valuable qualities of the cotton lint.

Economic Importance: Cotton is one of the largest crops produced in this country and it is evident that whatever can be done to improve the quality of the finished product without unduly increasing the cost of preparation will be of tremendous economic and social importance not only to the cotton farmers but to the entire nation.

Estimated Annual Savings: No estimate can be made of the annual savings which have resulted from the improvements already developed in the methods of ginning cotton. As an example of what may be expected when these processes come into general practice, it may be said that it has been found that the artificial drying of seed cotton has saved from 60¢ to as much as \$5.00 or more a bale. This process has also been very effective in reducing the cost of ginning since thoroughly dried cotton gins with less power and less interruption from stoppages and ginning can be carried on continuously without reference to weather conditions.

This project is being carried on in cooperation with the Bureau of Agricultural Economics. No similar project is being carried on by State experiment stations.



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